AN APPRAISAL OF THE DEVELOPMENTS IN THE REPRODUCTION OF COLOUR IN COMPUTER PUBLISHING SYSTEMS

Thesis

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AN APPRAISAL OF THE DEVELOPMENTS IN THE REPRODUCTION OF COLOUR IN COMPUTER PUBLISHING SYSTEMS

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A thesis submitted in partial fulfilment of the requirements of the Open University for the degree of Bachelor of Philosophy.

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DECLARATION

I hereby declare that this dissertation is the result of my own work and that due reference is made where necessary to the work of other researchers and authors.

I further declare that this dissertation has not been accepted in substance for any former degree and is not currently submitted in candidature for any other degree.

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ABSTRACT

The plethora of coloured images that are reproduced in any printed media is facilitated through a variety of related processes that collectively constitute traditional printing techniques. The aim of this research is to appraise recent developments that have occurred within the colour prepress process. The colour prepress process involves the preparation of colour separated halftone films that are used in the production of offset lithographic printing plates. Over recent years the application of desktop publishing technology to perform many of the functions associated with the colour prepress process has raised a number of significant issues and debates.

The reproduction of coloured images in the printed medium demands that certain fundamental criteria are adhered to in order to maintain professional standards of colour fidelity. Such criteria include: successful digital halftone production, the elimination of moiré patterns, and maintaining colour fidelity between the coloured original and the coloured reproduction. This research thesis shall therefore establish the principles and techniques involved in the reproduction of colour in a printed medium. It will also asses whether desktop publishing systems are able to facilitate successful professional colour reproduction by examining current debates that challenge the viability of desktop publishing solutions. Current debates concerning desktop publishing solutions are primarily concerned with assessing the value of Adobe PostScript level 2 solutions, computer interchange spaces for colour matching purposes, and rational supercell techniques that attempt to eliminate moiré patterns. The research also attempts to establish the validity of current debate findings by comparing them with statistics derived from a questionnaire (undertaken as part of the research program) that seeks the opinions of system users on the effectiveness of their individual systems at processing and delivering acceptable colour separations.

1.0. Introduction

The primary aim of this research is to perform "An Appraisal of the Developments in the Reproduction of Colour in Computer Publishing Systems". Therefore, it is appropriate within the initial stages of the investigation to provide justification as to why such an investigation is worthwhile. The introductory stages will also endeavour to identify which particular facets of colour prepress warrant an in - depth evaluation, as well as outlining the reasons for their inclusion within the investigation.

The appraisal is justifiable if one considers the following extract from a recent Seybold conference flyer.

> *Colour is everywhere, and so is confusion. At our recent Seybold Paris there was an overwhelming sense of confusion about how to build colour systems and how to maintain quality and throughput. Some of our disarray may stem from the difficulties of the technology, some may come from differences of expectation. We need to understand what we should expect from colour systems, and at what price? Where does PostScript fit for high volume, high quality applications? How do we bridge the cultural divide between the needs of the traditional repro users and the desires of the desktop colour sophisticates?* [SEY93].

It is apparent from the above extract that there is an urgent need for an appraisal of emerging colour prepress technologies and applications, as well as a requirement to enhance knowledge within the prepress field. In order to ensure a comprehensive and thorough appraisal of emerging colour prepress technologies and applications a number of key objectives need to be successfully addressed. These objectives are:

- To establish the principles and techniques involved in the reproduction of colour in a printed medium.

- To assess whether desktop publishing systems are able to facilitate professional colour reproduction by examining current debates that challenge the viability of desktop publishing solutions.

- To determine the validity of current debate findings by comparing them with statistics derived from a questionnaire (undertaken as part of the research programme) that seeks the opinions of system users on the effectiveness of their individual systems at processing and delivering acceptable colour separations.

Satisfying each of the above objectives demands an in - depth evaluation of a number of important related topics. Such topics include:

<u>The Recent History and Fundamentals of Colour Reproduction in the Graphics Arts Industry.</u>

The history of the colour reproduction in the graphics arts industry using digital/ electronic techniques is relatively short. Only twenty years ago, high end digital prepress was the "coming revolution", threatening to displace traditional camera-based colour separations. However, with the continuing evolution of lower end desktop systems "traditional" prepress systems have found themselves being rapidly substituted in favour of lower end desktop publishing (DTP) solutions.

In order to understand the fundamentals of colour reproduction there are a number of specific themes that need to be addressed . Such themes include an awareness of colour models, an insight into the mechanics of digital halftoning, and techniques associated with colour separation.

An examination of the recent history and fundamentals of colour reproduction in the graphics arts industry would in part reveal what constitute common standards within the prepress industry in relation to the performance and capability of prepress systems. This in itself will assist in establishing the criteria necessary for the successful reproduction of colour in a printed media.

Problems of Professional Colour Image Processing with Desktop Systems.

Digital image processing in the graphic arts industry has always been characterised by the huge volume of data that requires manipulation and transmission to varying devices. The vast amount of data required for high resolution, pixel intensive images has traditionally been processed by proprietary systems specifically designed for the purpose. The development of such systems inevitably led to expensive hardware and software solutions which prohibited simple interfacing between varying systems from a select number of competing manufacturers.

Through the late 1980s the continuing development of desktop publishing (DTP) systems employing widely available microcomputer technology began to offer cheaper solutions. However despite these developments, problems existed that inhibited the acceptance of DTP solutions as a viable alternative. The more significant problems encountered using lower end systems included: the moiré phenomenon, colour matching difficulties, production of vignettes, providing good traps, and the selection of a computer interchange space for colour conversion between various media.

The purpose of identifying problems encountered in the application of desktop technology to process high end colour work is to determine which problems remain unresolved. Those problems that remain unresolved are likely to be the focus of current research trends aimed at their resolution. As a consequence of this the research shall identify which research trends/current debates warrant further investigation.

Current Solutions Offered Within the Colour Desktop Environment.

Since the inception of desktop publishing in 1985 a variety of emerging solutions have been developed and applied in an attempt to eliminate the problems associated with the rendering of professional colour described earlier. The more significant colour solutions which have emerged, and continue to emerge, that justify attention include: CIE based solutions for colour matching, rational supercell/FM screening solutions that strive to eliminate the moiré phenomenon, and other peripheral solutions aimed at improving the prepress process.

A review of current solutions offered within the colour desktop environment becomes imperative in order to ascertain: the current technological trends within the colour industry, the nature of de facto industry standards, and the direction of future developments within colour prepress.

An Appraisal of Current Debates on Emerging Prepress Colour Solutions.

There are a number of eminent writers who regularly publish their opinions on the most recent colour prepress technological developments. Their opinions can often influence the colour prepress community as to the viability of such developments. An appraisal of current debates that challenge the viability of desktop publishing solutions will in part assess whether desktop publishing systems are able to facilitate professional colour reproduction in a printed media.

As indicated earlier a questionnaire survey that seeks the opinions of system users is to be used to validate current debate findings by comparing them with statistics derived from the survey.

Given the above it is clear that a successful appraisal of emerging colour prepress technologies and applications is reliant upon satisfying the key objectives of the research through an in-depth review of the topics outlined. Those topics introduced provide a very brief and informal insight into what each topic entails. Of course more detailed and comprehensive analysis is included within the major content of the investigation. However, it is worthwhile reviewing the themes and concepts of each of the topics at this introductory stage. Also the manner in which the topics are segregated is indicative of how the major chapters of the thesis manifest themselves in terms of formula and content.

2.0. Methodology

Having ascertained the objectives of the research it became imperative that appropriate methods of research were selected in order to ensure that these objectives were met. Therefore the intention of this chapter is to outline which methods of research were implemented as well as explaining the rationale behind their selection.

The initial objective of the research involved establishing the criteria necessary for the successful reproduction of colour in a printed media. In order to facilitate this objective the research primarily involved a review of existing prepress literature. Through an examination of *standard* prepress literature it was anticipated that the principles and techniques involved in the reproduction of colour in a printed media would be identified. Establishing which facets of prepress literature constituted *standard* reading involved referring to a previous research program carried out by this author at first degree level. As a consequence of referring to previous work it became evident that the majority of standard prepress literature manifested itself in textbook type publications available from graphic arts institutions (e.g. GATF). Titles that were considered to be relevant to the research were obtained either through private acquisition or via the inter - library loan facility. Examples of titles used to establish the criteria necessary for the successful reproduction of colour in a printed media are included within the bibliography.

The titles of those publications used within the research are indicative of the nature and level of prepress literature that was employed within the initial research. The reasoning behind referring to *standard* prepress literature in order to determine the principles and techniques involved in the reproduction of colour images was a belief that such literature would itself be based upon standards widely recognised within the prepress industry.

Another method with which to establish the criteria necessary for the successful reproduction of coloured images involved correspondence with a select number of application manufacturers. Those manufacturers contacted were:-

Adobe Systems Europe B.V. (The Netherlands)

Agfa - Gaevert (Brentford).

Apple Computer U.K. (Uxbridge)

Barco Graphics (Reading)

Crosfield Electronics Ltd (Hemel Hempstead)

Dainippon Screen (London)

ECRM (Hertfordshire)

Highwater Design (Cheltenham)

Hyphen (Hertfordshire)

International Prepress Association (U.S.A)

Linotype - Hell Ltd (Cheltenham)

Monotype Systems (Redhill)

Purup Prepress (Old Isleworth)

Scangraphic Visutek Ltd (Leatherhead)

Scitex U.K Ltd (London)

Sony U.K (Basingstoke)

An example of a typical letter sent to a prepress manufacturer is shown in the appendix as figure A2.

The rationale underlying correspondence with manufacturers of prepress colour applications was the assumption that such organisations would provide literature relating to their equipment and product ranges. Therefore a thorough analysis of hardware/software specifications and manufacturers documentation would in part reveal what constitutes common standards within the prepress industry in relation to the performance and capability of prepress systems.

Probably the most important objective of the research was to establish whether desktop publishing systems are able to facilitate professional colour reproduction in a printed media. This objective was to be achieved by examining current debates that challenge the validity of desktop publishing solutions. Current debates manifest themselves as papers and articles presented in reputable prepress journals or as proceedings from prepress conferences and seminars. Examples of the current debates used within this research (e.g. Seybold Reports, TAGA papers etc) are itemised within the bibliography, and the authors of these sources are cited throughout the main body of the thesis.

Examining current debates as a means of establishing the validity of desktop publishing systems is justifiable if one considers that such debates are often derived from the findings of extensive research programmes. Therefore it is highly probable that such debates are well founded and deserving of investigation. However, it is vital that the research performs an appraisal of these debates through a process of a critical/literature review and by comparing them with statistics derived from a questionnaire (undertaken as part of the research program) that seeks the opinions of system users on the effectiveness of their individual systems at processing and delivering acceptable colour.

The selection of a questionnaire survey as a means of evaluating whether current debates are warranted is based upon the assumption that seeking users opinions would provide a valid evaluation of emerging colour solutions as they are used in the commercial environment for which they were designed. The methodology employed within the questionnaire survey is outlined in detail in chapter seven.

Another method through which users opinions were accumulated was to assign a posting on the *comp. publish.prepress* computer bulletin board. The posting involved a request for co-operation which required prepress users to relate their experiences of using PostScript colour *solutions* on specific issues of quality and performance. The posting itself is shown in the appendix as figure A2.

The primary reason behind using the bulletin board as a means of accumulating users opinions was that the response rate experienced during the questionnaire survey was significantly lower than had been originally anticipated. However, the bulletin board provided an opportunity to access a potentially huge sample group incorporating users in the UK. and the United States.

All of the above methods represent the manner in which the research program was conducted. It is believed that each of the methods selected would satisfy the objectives of the research program.

3.0. The Recent History and Fundamentals of Colour Reproduction Within Graphic Arts.

3.1 The Recent History of Colour Reproduction in the Graphic Arts

Understanding the recent history of colour reproduction within the graphic arts environment requires a familiarity with the evolution of colour separation technologies. The evolution of colour separation technologies within the ever-changing colour prepress market has experienced rapid acceleration over the past thirty years or so.

During the 1960s the colour separation process involved the use of reprographic cameras employing photographic screens and masking techniques. Using camera based techniques to achieve colour separation involved a multitude of time consuming labour intensive stages. Each stage of the process required a highly skilled camera operator mounting, exposing and developing an individual piece of film for that stage. The more demanding stages involved camera operators applying photographic screens, masks, and tints.

During the 1970s and '80s analogue scanners that store and manipulate colour data as varying electrical voltages began to supplant camera based separations [MOL88]. In the latter period of the 1980s analogue scanners were in the process of being substituted in favour of digital scanners that manipulate colour data as discrete ones and zeros, thus offering interfacing opportunities with high-speed digital computers. At the present time the most widely accepted tools for colour separation involve a configuration of lower-end desktop solutions that are used for simple layout and typesetting purposes, while high-end digital scanners are still primarily employed to perform colour separations [KIE91].

Inevitably the next stage in the evolution of colour prepress will involve the use of desktop-type computers to perform their own colour separation entirely. Although lower end desktop systems that perform colour separation (based on Postscript level 2-type technology) already exist, their acceptance as a viable alternative by the prepress community has been relatively slow in comparison with other microcomputer application phenomena. The issues of desktop speed and quality in relation to their high-end competitors has it is believed, inhibited an industry-wide implementation of the desktop. However, recent developments in processor speeds, mass storage availability, rational supercell technology, and the CIE interchange colour space have to a greater extent addressed the issues of speed and quality. The percentage of colour separations generated entirely on the desktop is relatively small in the U.S.A. [KIE91]. However the proportion of the work allocated to the desktop is increasing rapidly as a result of the developments outlined earlier. It would seem then that as these developments continue to evolve, desktop colour separations will dominate the colour prepress market in the near future .

3.2 Fundamentals of Colour Reproduction in Graphic Arts

In graphic arts there are a number of specific topics that need to be addressed in order to understand the more rudimentary issues associated with colour reproduction. Such topics include: the experience of colour, an awareness of colour models, an insight into the mechanics of digital halftoning, and techniques associated with colour separation.

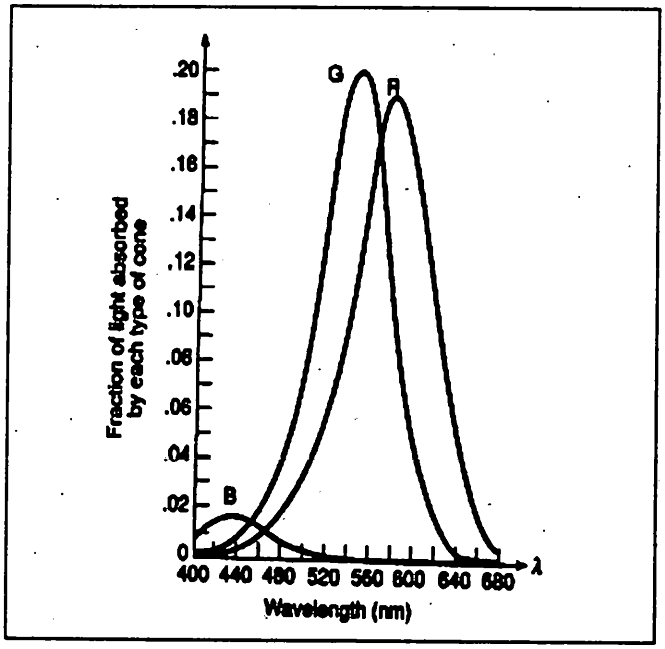
3.2.1 The Experience of Colour

In contemplating the experience of colour it becomes clear that *colour is an immensely complex subject, one that draws on concepts and results from physics, psychology, physiology, art, and graphic design* [FOL90].

The human experience of colour is a mental perception of light received by the eye. Therefore the manner in which an individual distinguishes colour is subjective and open to interpretation. The subjective nature of colour raises psychological issues. The ability of colours to evoke strong emotional responses is obvious. According to its hue, a colour can be classified as warm or cool, light or dark, vivid or dull, created or natural. Colour therefore is a sophisticated phenomenon with a strong emotional effect that makes the appropriate choice of different colours essential in art, design, and commerce.

The ability to perceive colour is facilitated through light sensitive cells contained within the retina of the eye. There are two distinct groups of light sensitive cells i.e. rod-shaped cells and cone-shaped cells. The *cone-shaped cells can be sub-divided into three categories with each category having a peak sensitivity to one of the light primaries (red 580nm, green 545nm, blue 440nm) see figure 3.1 . Whatever the mechanism all colour we see is the product of signals coming from the three categories of cone cells* [FOL90].

Fig. 3.1. Spectral-Respnse Functions of Each of the Three Cones of the Human Retina.



Source: Foley, J; Computer Graphics (Principles & Practices) 2nd Ed., 1990.

Given that each person's ability to distinguish colours from one another is subject to emotion and other contributory factors, the need arose to measure and communicate colour data in an objective and quantitative manner.

Probably one of the more critical objectives involved in obtaining "standardised" colour measurement is to define a standard source of illumination under which a coloured object is viewed. This resolves any ambiguities in viewing conditions and permits the calibration of colours as they progress through the various stages in the print production process [KIE 91]. The standard relating to viewing conditions involves specifying the colour temperature. Physicists establish the *colour temperature* by specifying the glow given off by an ideal substance, or *blackbody* , as it is heated to various temperatures measured in degrees Kelvin(K). In order to minimise variations in colour perception, the North American Graphics Arts industry has established 5000K as a standard light source for viewing colour originals, proofs, and printed samples.

In order for a computer to work with colours, they must be quantifiable and described numerically. That is, every colour must be reduced to a binary representation. The attempt to quantify colours using a numerical representation has resulted in the development and application of various colour models.

3.2.2 Colour Models

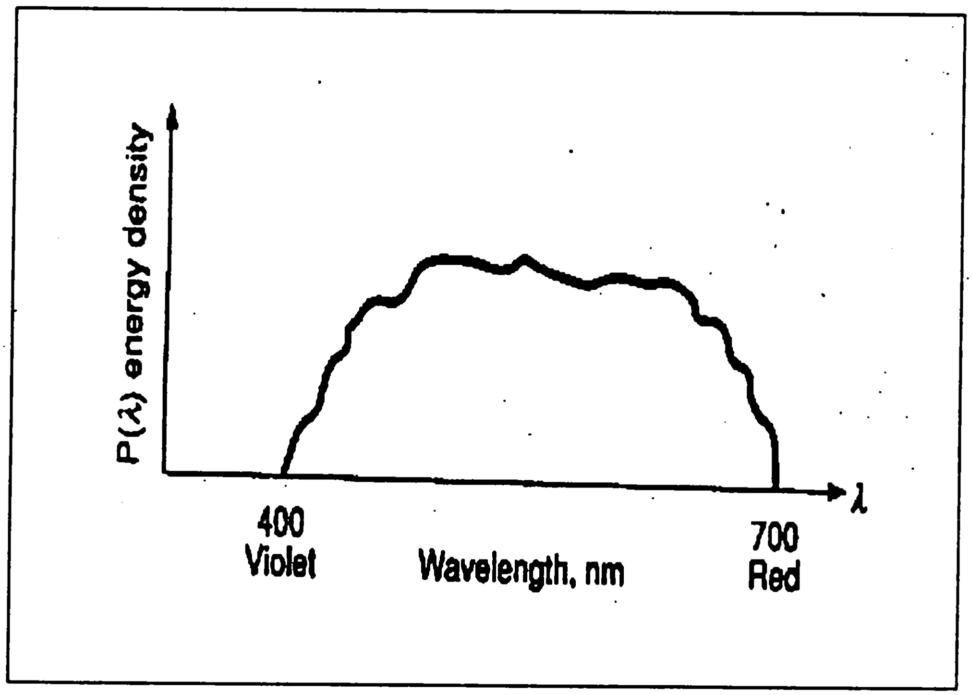
A colour model is a way of representing colours as data. As mentioned earlier, colour is affected by perception and, therefore, colour models are imperfect. However, people who use colour in the prepress and printing environment must have a consistent way of describing it [KIE91].

Colour models are based on the principles of a branch of physics known as *colorimetry*. Important terms in colorimetry are *dominant wavelength*, *excitation purity*, and *luminance*.

Dominant wavelength is the wavelength of the colour we "see" when viewing the light, and corresponds to the perceptual notion of hue; excitation purity corresponds to the saturation of the colour; luminance is the intensity of light (Lightness, Brightness). A completely pure colour is 100% saturated and thus contains no white light, whereas mixtures of a pure colour and white light have saturations between 0 and 100%. White light and greys are 0% saturated, containing no colour of any dominant wavelength.

Fundamentally, light is electromagnetic energy in the 400 to 700nm wavelength part of the spectrum, which is perceived as the rainbow of colours from violet through to red [FOL90] see figure 3.2.

Fig. 3.2. Typical Spectral Energy Distribution P(λ) of a Light.



Source: Foley, J; Computer Graphics (Principles and Practices) 2nd Ed., 1990.

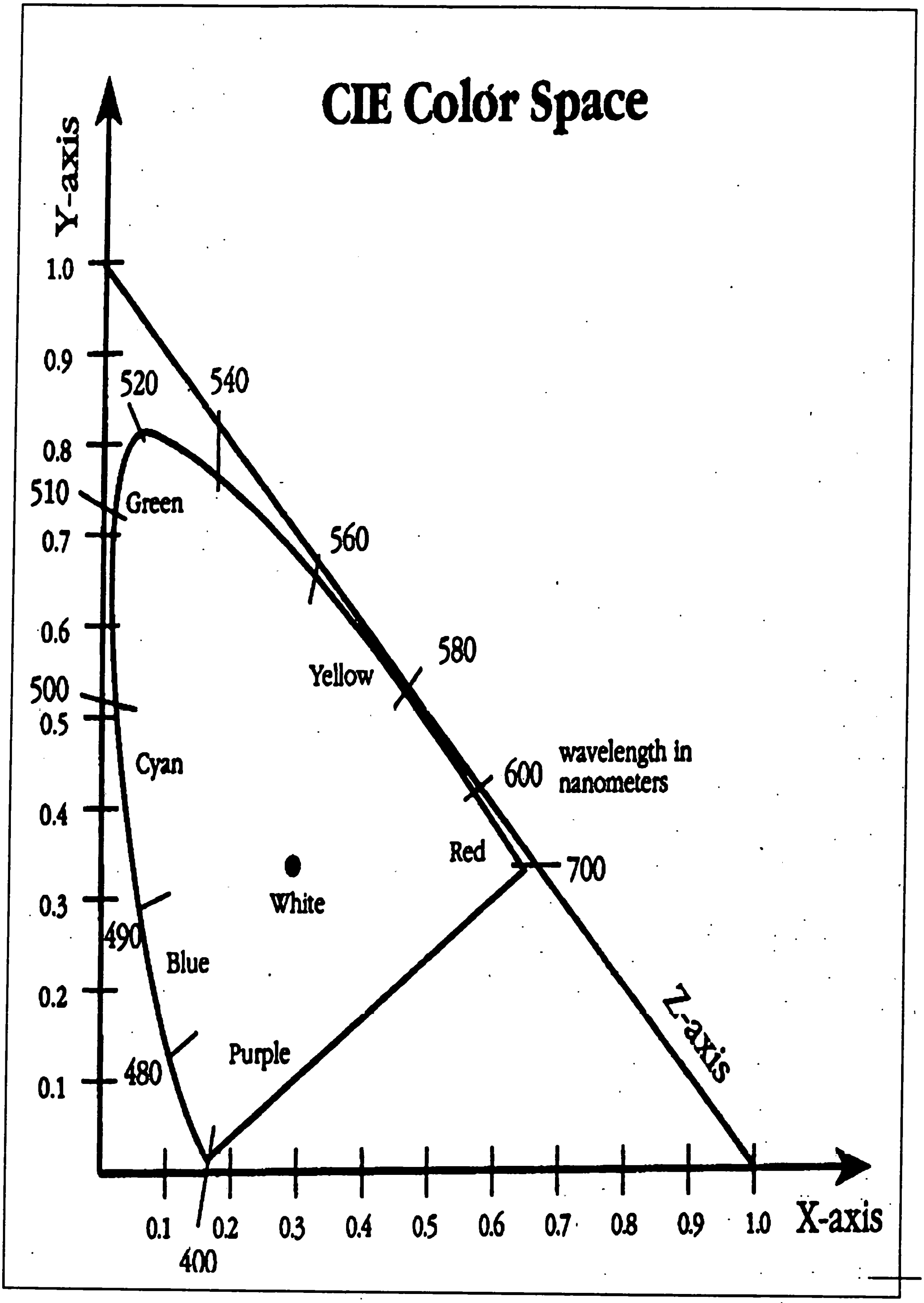
The amount of energy present at each wavelength is represented by a spectral distribution. In practice the distribution is represented by a large number of sample points on the visible spectrum, as measured by a spectroradiometer. Fortunately, describing the visual effect of any spectral distribution (colour) can be achieved much more concisely by specifying its tristimulus values. The concise description of colours using tristimulus models has resulted in the evolution and application of the following colour models:

CIE Colour Model- All computers, software, and peripherals must use a colour model internally for specifying colour. Colour research has been directed towards establishing a colour model that is independent of any particular device and based on the way the human eye perceives colour, rather than the way colour is interpreted by an input scanner or rendered by a particular output device. The concept of device-independent colour was developed in the 1920s by an international scientific commission on illumination, the Commission de l'Eclairage (CIE). *Its 1931 model is based on the notion of a "standard observer" whose colour vision is described in terms of spectral sensitivity of red, green, and blue receptors in their eyes* [KIE91].

The original CIE chromacity diagram (see figure 3.3.overleaf) has several drawbacks; namely, it was designed for measuring the colour of light sources rather than the colour of objects, equal distances on the diagram do not correspond to equal visual differences, and it is conceptually awkward to explain in terms of normal colour descriptors [FIE92].

In order to address some of the drawbacks of their original chromacity diagram the

Fig. 3.3. The CIE Colour Space



Source: Kieran, M., Desktop Publishing in Color, p9, 1990.

CIE introduced two new transformations of the chromacity diagram in 1976. The transformations introduced were the L*, A*, B* system (CIELAB) and the L*, U*, V* system (CIELUV).

Under the L*, A*, B* system the L element corresponds to the lightness value of a colour, while hue and chroma(saturation) are expressed as A and B. In practice if the coloured sample below was measured using a ChromaMeter (supplied by the Minolta Corporation) the tristimulus values of that colour were L* = 42.83, A* = 45.04, B* = 9.52. A* and B* indicate two colour axes, with A* the red-green axis and B* the yellow-blue axis. Using the values for A* and B* it is now possible to plot the intersection of their respective values (A* = 45.04, B* = 9.52) as point 1 on the L*A*B* colour chart (hue and chroma) shown below as figure 3.4.

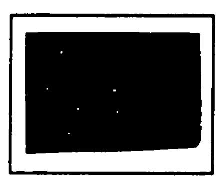
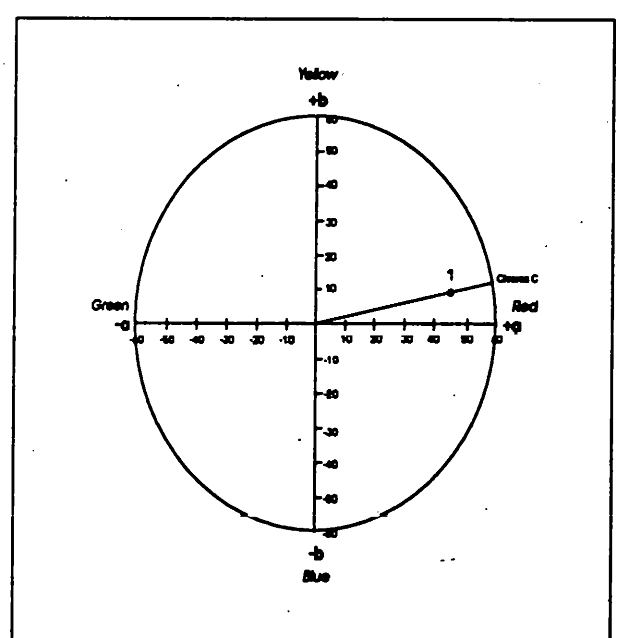


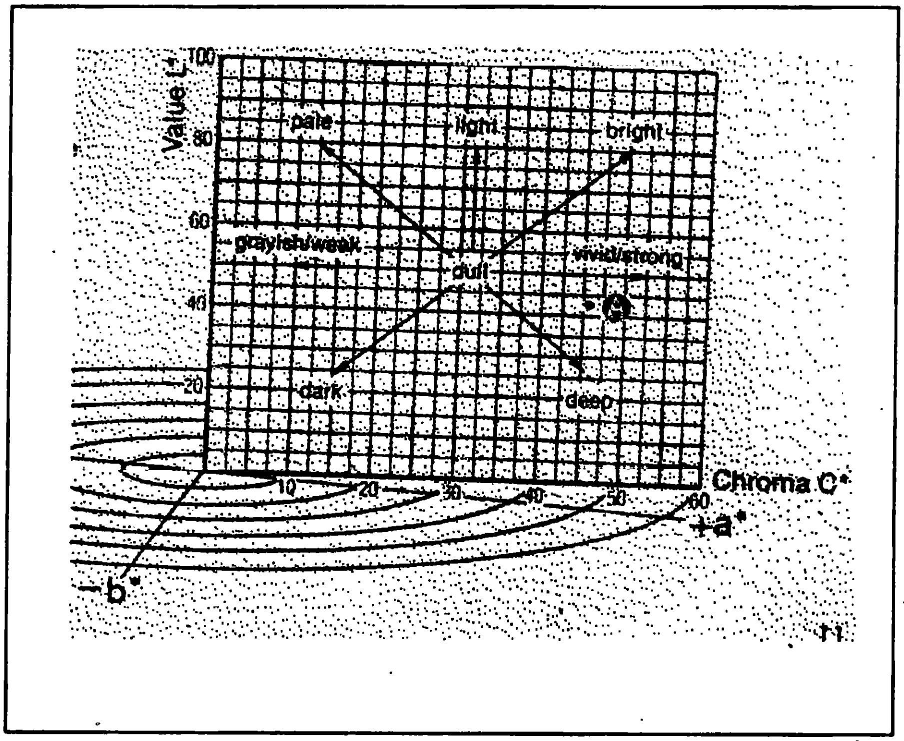
Fig 3.4. <u>The CIE.LAB Colour Chart.</u>



Source: Minolta Camera Co., Precise Color Communication, p11, 1989.

In order to plot the final intersection of all three values i.e. the L* value (42.83) consider that that the hue and chroma colour chart in figure 3.3. has been rotated 90 degrees with the value L* extended above the line drawn from the centre through chroma C. The intersection of all three values is shown in figure 3.5. If this were expressed in general terminology it would be described as a vivid red purple.

Fig. 3.5. <u>Intersection of the Three CIE.LAB Axes.</u>



Source: Minolta Camera Co., Precise Color Communication, p11, 1989.

Under the CIELUV system the U* value is similar to the A* value in the CIELAB in that it indicates the redness-greenness component of a colour. Likewise the V* value is similar to the B* value in that it refers to the yellowness-blueness component of a colour.

Selecting which CIE colour space is appropriate depends on a number of factors.

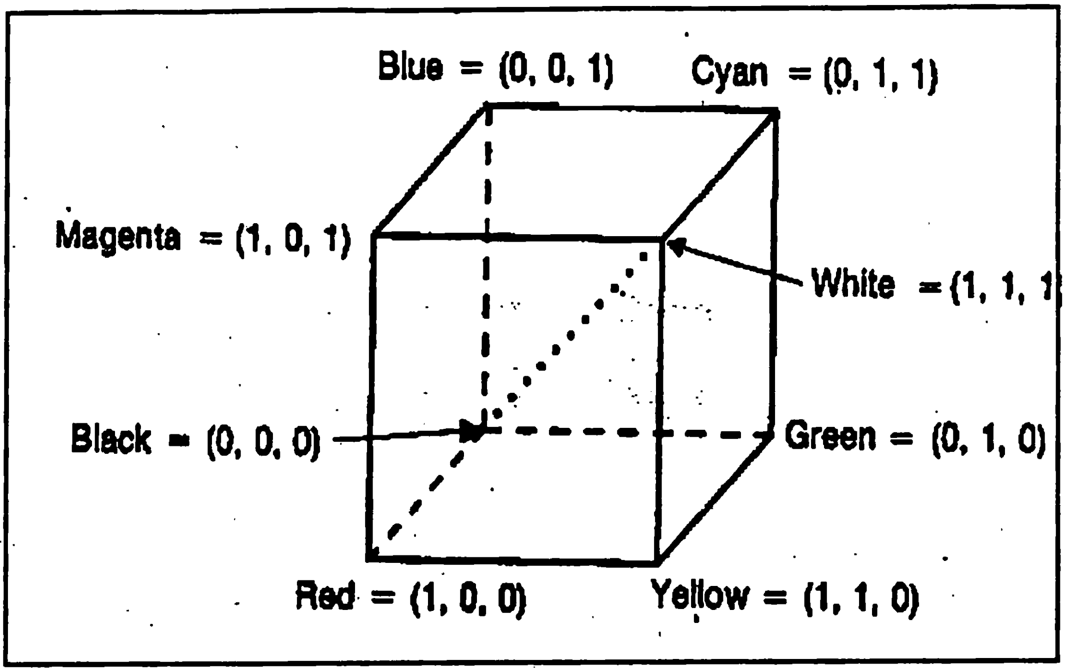
Billmeyer and Saltzman suggest in their book (*Principles of Color Technology, 2nd Edition, NY Wiley, 1981, pp. 47-66, 85-106*) that CIELUV might be preferred when measuring colour reproductions and that CIELAB might be preferred for measuring flat colours such as paints or plastics. *The CIE Colorimetry Committee intended CIELAB for the measurement of small colour differences and CIELUV for the measurement of large colour differences such as those found in colour reproductions. Billmeyer and Saltzman report that there is little difference in how well (or how poorly) CIELUV and CIELAB agree with visual data* [FIE92].

To date, no individual or research centre has devised a completely satisfactory way of specifying device independent colour. However, a considerable amount of research continues to be directed at this elusive problem [JOH92]. Adobe has selected CIEXYZ as the internal colour model in PostScript Level 2, with built-in conversions to other leading colour models.

RGB Colour Model- The RGB model, based on combinations of red, green, and blue light to compose all colours within the RGB colour gamut, is used for light emission and cathode ray tube (CRT) monitor displays. The RGB colour model is additive that is the individual contributions of each primary (i.e. RGB) are added together to yield the desired colour result. A major limitation of the RGB system is that because it is based on adding colours together, it works for devices that radiate light, such as monitors, but not for objects that reflect light such as the printed page.

Most often, the RGB colour model is depicted by a cube where each of the three opposing corners on the main axes is a primary colour; see figure 3.6.overleaf. The remaining corners are the three secondary colours, and black and white (at the origin). Greys are found on the black / white axis; red is opposite to cyan, green to magenta, and blue to yellow. [SOS91].

Fig. 3.6. The RGB Cube



Source: Sosiniski, B., Beyond The Desktop, p 437, 1991.

RGB colours may be quantified and then translated to the Hue, Saturation, Lightness (HSL) colour model for a particular device. Axes are normalised to 1, and colours are a vector sum of components. RGB values are not, however, related in a linear fashion to phosphor intensity on a monitor and therefore require a look-up table for display. The values determined for each monitor are unique. RGB is the current standard for computer graphics, and conversion has been determined for most other colour models. *RGB emphasises hardware implementation of colour at the expense of colour perception. Put another way, RGB space is perceptually non uniform* [SOS91].

Two other models that are closely related to RGB are HSL and HSV (the V stands for value). HSL and HSV are mappings of RGB space into transformations that attempt to model perceptual colour. These models are limited by hardware and are not specifically related to colour perception. HSL is represented by a cylindrical coordinate system transformed into a cube. The resultant shape is a double hexacone. HSV takes RGB space and tilts the cube on it's "back" corner. These models are sometimes used in paint programs because they yield easy to use controls, but require more complex mathematics to describe composite colours. Both systems also yield unique monitor calibration values.

CMYK Colour Model- Practically speaking, the CMYK (cyan, magenta, yellow, and black) model is among the most important of colour models, as it is the basis of almost all colour reproduction processes. Combining percentages of the four process colour inks (CMYK) on a press produces the appearance of millions of colours.

Cyan, magenta, and yellow are the complements of red green and blue, respectively. When used as filters to subtract colour from white light, they are termed subtractive primaries. *Colours are specified by what is removed or subtracted from white light rather than what is added to blackness. Therefore, the origin of the CMY model is white light instead of black light which is the origin of the RGB model* [FOL90].

In theory at least, it should be possible to print full-colour images with only CMY, the complements of RGB. In reality however, the inks, papers, and presses used do not make this possible; a combination of pure cyan, magenta, and yellow, does not produce a solid black but, rather, a muddy brown, the result of both imperfect colour pigments and lack of density.

These problems are resolved to some extent, in the colour separation process. To increase density, especially in the dark areas of the image, black ink is added to cyan, magenta, and yellow. In full-colour imaging, the problem of imperfect ink pigments is solved by having the scanner operator key in adjustments to the relative strengths of the different inks. Similar compensations have to be made in desktop colour separation programs.

3.2.3 Colour Reproduction and Halftones

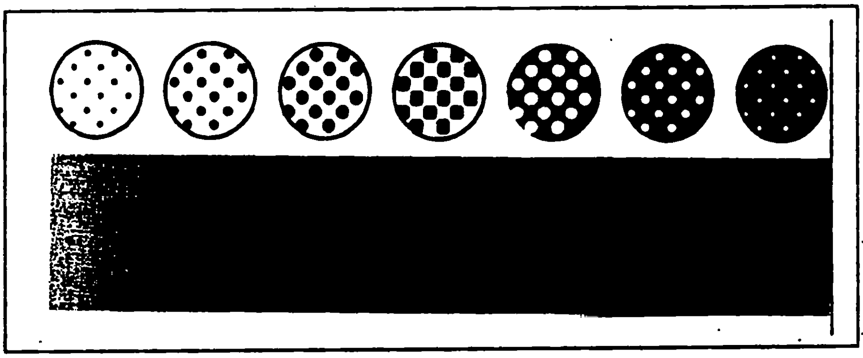
The principle of mass colour image reproduction is based upon the fact that most printable colours can be achieved (or at least approximated) by applying various mixtures of only three or four of the process inks (CMYK). An integral feature of using process inks to simulate continuous colour images is halftoning.

Halftoning is a process that is long established within the offset printing environment, in which a finely etched screen is positioned between the image and a piece of photographic film or paper, then exposed. This recreates the image as a pattern of black dots or spots on the photographic medium. The halftone dots are larger in dark areas of the image and smaller in light areas.

The colour separation process requires that a halftone screen be created for each of the four process colours. When the process colours are printed, the cyan, magenta, yellow, and black inks will overprint in various combinations, depending on the density of each halftone. It is the blending of these multiple screened inks that creates, in the perception of the viewer, the appearance of countless colours.

A halftone is really an illusion, a precise grid of dots that the eye converts into the appearance of objects and levels of grey. As shown in figure 3.7, the halftone illusion is revealed by enlarging the reproduction to show the individual dots that make up the image.

Fig 3.7. The Halftone Illusion.



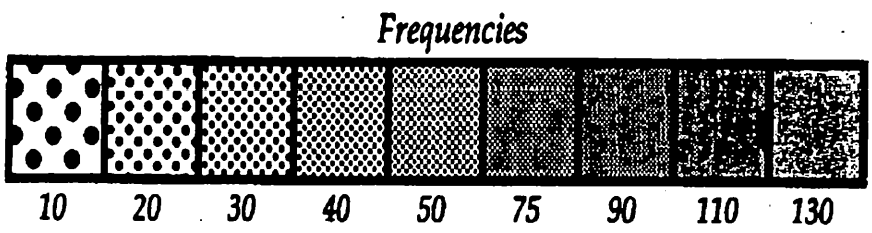
Source: Sosiniski, B., Beyond The Desktop, p 473, 1991

The reason for the necessity of halftones is that the offset lithographic process can only print or not print and cannot support a continuos blend of ink, but is instead built from thousands of tiny dots. Typically, in colour halftoning, the dots are cyan, magenta, yellow, and black. The size of the coloured dots as they relate to one another determines the colour perceived. For example, the larger the cyan dot (as compared to magenta, yellow, and black), the more cyan is contained in the perceived colour. The halftone principle applies equally to black and white photographs and tints of grey. By controlling the size of the dots, it is possible to achieve a full tonal from white through the grey scale to solid black.

The screening process creates patterns that are made up of dots, and although the dots are usually square, round, or elliptical, they can be any other shape. The key concept is that, while the size of the halftone dots changes within an image, the basic pattern of dots remains the same. However, there are three variables that affect halftone screen, these include:

Frequency- The frequency component of the halftone screen is the number of halftone lines/cells per inch. It is important not to confuse lines per inch(lpi) with dots per inch(dpi).In general the halftone frequency affects the coarseness/subtlety of the printed image. *Newspapers commonly use 75- and 85-line screens, while most magazines use 120-,133-, or 150-line screens, and high quality art books often use 175- or 200-line screens, or above* [MAC92}. Figure 3.8. overleaf shows 25% black imaged with frequencies ranging from 10 lines/cells per inch to 150 cells per inch.

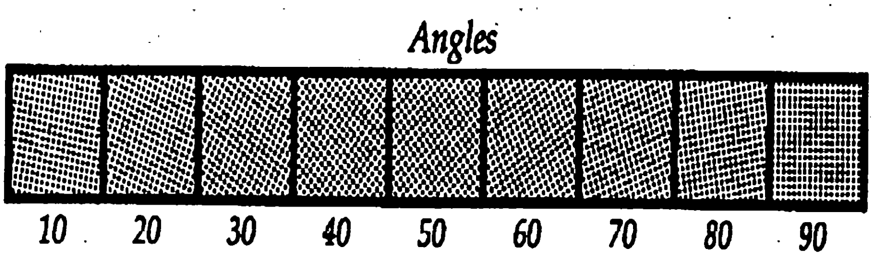
Fig. 3.8. 25% Black Imaged with Frequencies Ranging from 10 to 130lpi



Source: MacGilton, H., PostScript By Example, p529, 1992.

Angle: The angle element of a halftone screen defines the angle at which the halftone screen is placed over device space. Angle is expressed in degrees and represents the orientation of the screen relative to the horizontal axis of device space. *The screen angle in black- and- white printing is set to 45 degrees, in order to make the screen the least obstructive to the eye* [HUN87]. However in colour printing the screen angles and frequencies can play a major role, as will be shown later, in the elimination of moiré. Figure 3.9. shows 25% black imaged with angles ranging from 10 to 90 degrees respectively.

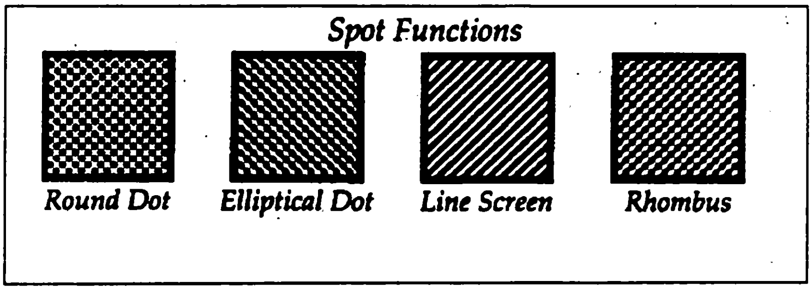
Fig. 3.9. 25% Black Imaged with Angles Ranging From 0 to 90 Degrees.



Source: MacGilton, H., PostScript By Example, p529, 1992.

Spot Function- Spot function is the essence of the halftone screen as it defines the shape of halftone dots. Figure 3.10 shows 50% grey using four different spot functions. *The spot function may help in making smooth-looking gradations , or some special effects* [AMI91].

Fig. 3.10. 50% Grey Imaged Using Four Different Spot Functions.



Source: MacGilton, H., PostScript By Example, p529, 1992.

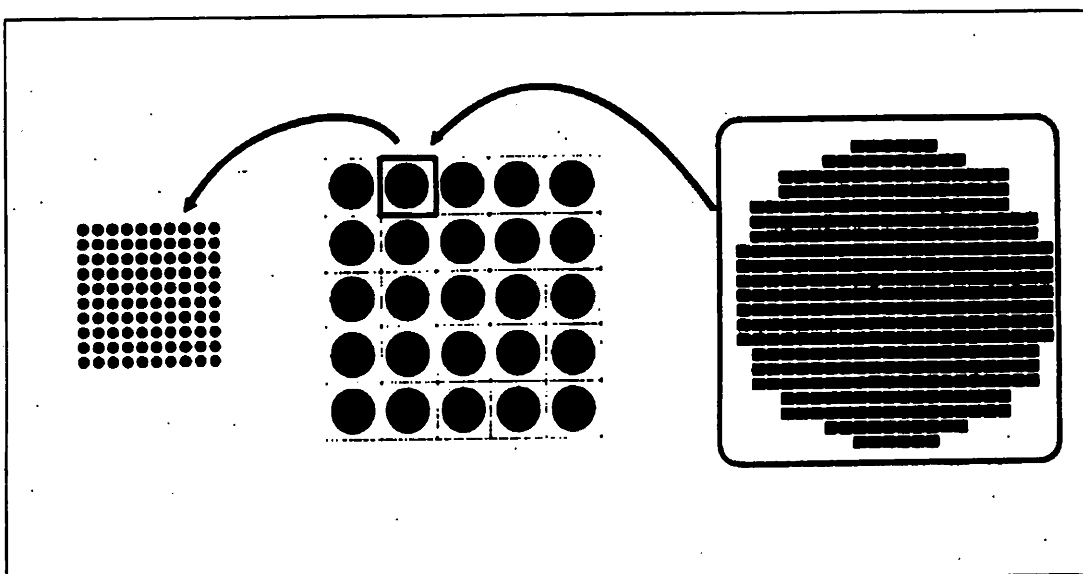
By adjusting the three variables outlined above, it is possible to create a variety of screen effects, from a coarse stubble for special effects to a fine grey fill that approximates a photograph. Using traditional photographic methods, all three are easily altered. A variety of different screens make it possible to change the frequency and dot shape, though this can be costly.

Photographic halftones are important to the electronic prepress community as laser printers and imagesetters like printing presses, are unable to produce shades of grey and continuous colour. The solution is to create an electronic equivalent of the photographic halftone i.e. the digital halftone.

Digital Halftoning- Photographic halftone dots have the ability to vary in size, however, a laser printer or imagesetter cannot vary the size of the laser pixels, and therefore must group together to produce halftone dots of different sizes.

Digital halftoning achieves the halftone effect used for photographs by grouping many different printer pixels together to form a halftone cell, such as the 75% grey cell in figure 3.11. Switching on and off individual laser pixels within the halftone cell can effectively change its size. The more pixels in a halftone cell, the more shades of grey that can be obtained. A group of 25 laser pixels in a 5-by-5 matrix produces 24 different shades of grey, plus all black (all pixels on) and white (all pixels off). All the pixels on gives 100% black area; if one pixel is off, the result is 96% black, and so on.

Fig. 3.11. 75% Digital Halftone Cell.



Source: Kieran, M., Desktop Publishing in Colour, P44, 1990.

Using a larger matrix of laser pixels for the halftone cell makes it possible to create more shades of grey: a 16-by-16 matrix contains 256 levels of grey, plus black and white. The inevitable trade-off in digital halftoning is that there are a limited number of grey tones that can be created for a given combination of output resolution and screen frequency.

Using a 5-by-5 halftone cell matrix and outputting on a 300 dpi laser printer produces 60 cells per inch (300/5) or a 60 line screen. However, it results in only 24 grey levels, while the human eye can detect hundreds of grey levels and requires at least 60 for the illusion of continuous grey tones, depending on the image[KIE91]. Therefore the solution is to print on an output device with higher resolution, making it possible to get all the grey levels (256) needed, at a sufficiently high screen frequency. An imagesetter at 2,540 dpi can use a 16-by-16 halftone cell matrix to produce 256 levels of grey with a screen frequency of approximately 150 cells/lines per inch (2540/16). The same principle applies in colour halftoning, where a 16-by-16 halftone cell matrix is used for each of the colour primaries used. For example a CMY halftones can yield 16.8 million colours (256x256x256), as each primary contains 256 levels.

3.2.4 Principles of Colour Separation in Graphic Arts

Throughout this thesis there are frequent references to the process of colour separation, and to the separated film that is the end product of the prepress process. Therefore, a thorough understanding of the principle governing colour separation is essential for all that follows.

As mentioned earlier, colour printing is based on the illusion that a few colours in combination appear to contain all the colours of the visible spectrum. A colour graphic created in a paint or draw program can be separated easily if its colours have been specified according to their CMYK values. With a little more work conversion tables are used for colours that were originally specified in another colour model. It is thus possible to create a graphic in an illustration package, specify its colours according to their CMYK values, and import it into a page layout program for integration with type and other graphics. The practice of building up coloured areas in a drawing through the use of tints is amongst the most important applications of desktop tools for colour production. It provides a much more powerful set of tools than traditional market renderings.

The practice of separating a coloured original artwork or photograph is more complex, although the process is analogous to the way the eye sees. The original is photographed using three filters each corresponding in colour to one of the additive primaries: RGB.

Placing a blue filter over the lens produces a negative recording of all the blue reflected or transmitted from the object producing a blue separation negative. When a positive (print) is made from this negative, the silver in the film will correspond to the green and red areas that absorbed blue.

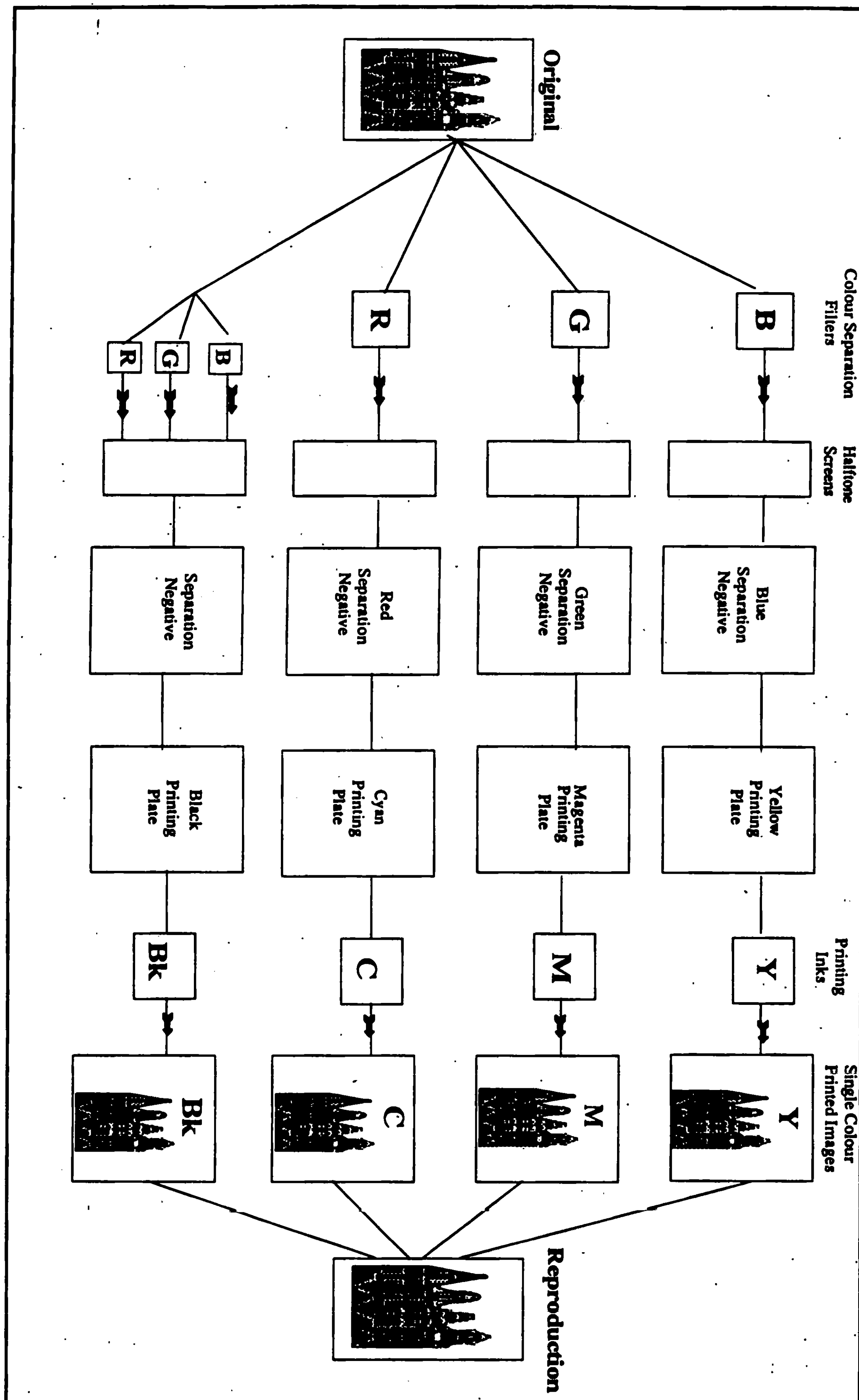
One way to think of this is that the negative has subtracted the blue light from the original object, and the positive is the recording of the green and red in the scene, the colour yellow. The positive is the yellow printer. Similarly shooting through the green filter creates a negative recording of the green in the original scene. The positive is the recording of the other additive primaries, red and blue, which produces the magenta printer.

Likewise, the red filter produces a negative recording of all the red in the subject. Its corresponding positive records the blue and green, which add together to produce the cyan printer. The general principle of colour separation described above is illustrated in figure 3.12 overleaf.

Electronic colour separation is facilitated through two distinct types of scanning technology: stored colour data scanners (digital scanners) and real time processing scanners (analogue scanners). However, the continuing evolution of low cost, high speed digital computers has enabled digital scanners to become the dominant method of performing electronic colour separation.

At the input end of the scanner, the colour original (photographic transparencies) is wrapped around a transparent drum, which revolves around the light source (usually

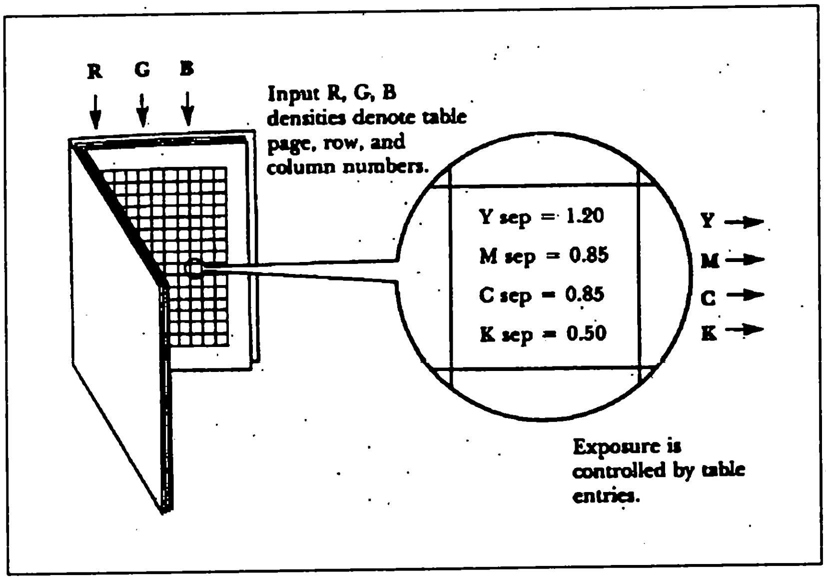
Fig 3.12. The Colour Separation Process



a Helium Neon laser). The light source can also be situated outside the drum for reflective art (photographs and prints). To colour separate the original, the laser beam is split into three beams after passing through, or being reflected from, the original. The intensity of each beam is measured by a photocell that is covered by a filter that corresponds to one of the RGB additive primaries, thus separating each area of the image into its three RGB components [KIE91].

The resultant RGB tristimulus values for each point of the original require conversion to their respective CMYK dot values which are output to film. Such conversion is usually facilitated through a look-up table approach. It is worthwhile to consider a look-up table as a book with the page, row and column numbers corresponding to the RGB tristimulus values respectively. Therefore, the red-filter value identifies the correct page in the book, the green filter is then used to locate the correct row on that page, and finally, the blue filter is used to locate the appropriate column in that row. This approach is demonstrated in figure 3.13.

Fig. 3.13. The Look-Up Table Approach.



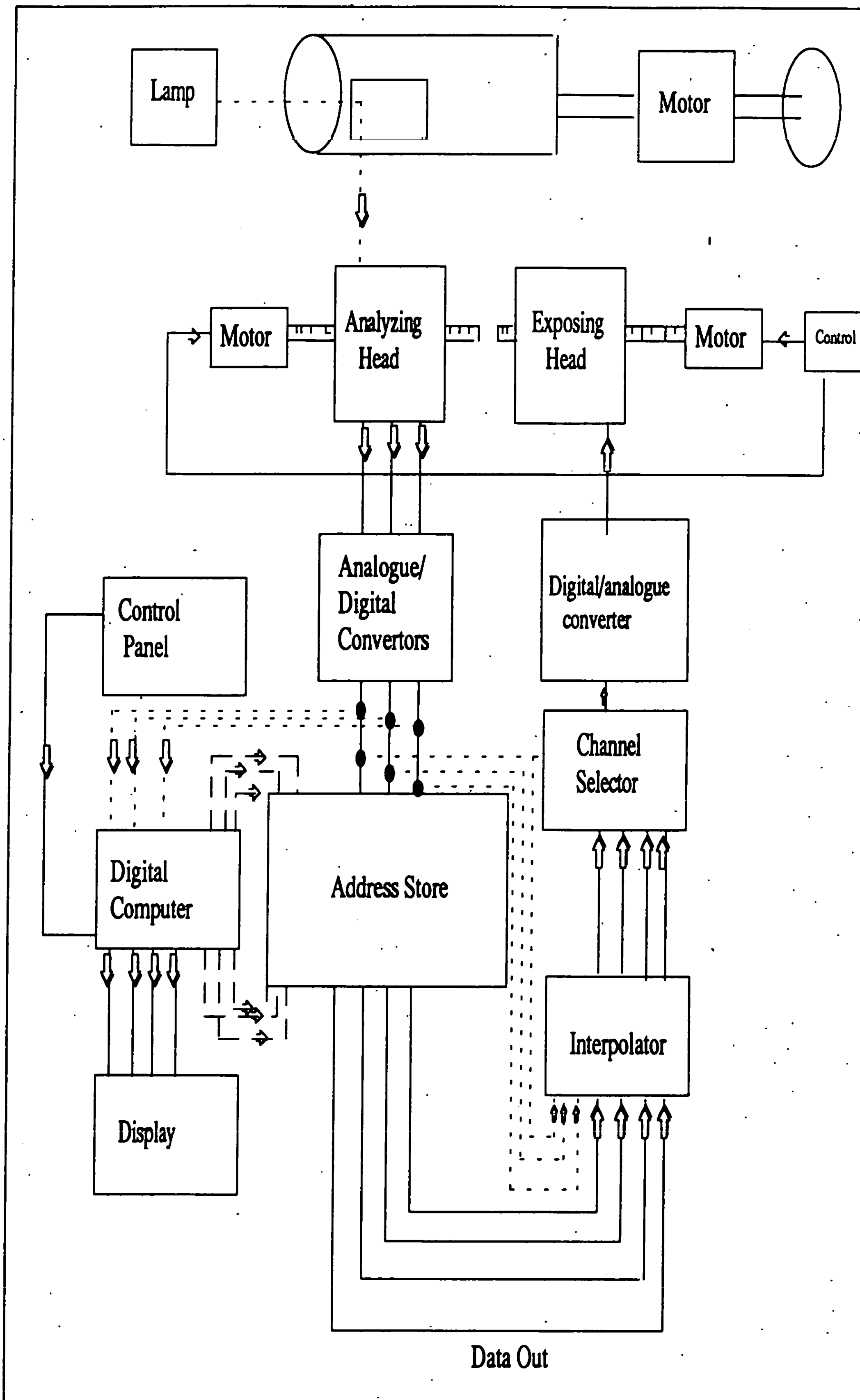
Source: Field, G., Color Scanning and Imaging Systems, GATF, 1990.

A typical digital scanner employing a look-up table approach is likely to incorporate the following stages in its conversion process.

> *1. Perform tone- and colour- correction operations in the normal manner on a series of trial colours.*
>
> *2. Store the trial colours in the form of their red-, green, and blue-filter signals, with their yellow, magenta, cyan, and black printing values as computed by the tone and colour circuits / programs.*
>
> *3. Set up a job on the scanner.*
>
> *4. Make any tone and colour adjustments necessary for the reproduction of the original.*
>
> *5. Transfer the adjustments to the memory and recompute the stored YMCK values.*
>
> *6. Scan the job.*
>
> *7. Search the memory for the "coarse" red, green, and blue values corresponding to the point of the original that is being analyzed.*
>
> *8. Use the fine "values" of the red, green, and blue, and the "coarse" outputs from the memory, to interpolate for the exact YMCK values.*
>
> *9. Use the YMCK signals to drive the exposing output light source.* [PUG75]

The components incorporated within a typical graphic arts scanner are shown overleaf in figure 3.14.

Fig. 3.14. Typical Graphic Arts Digital Scanner Configuration.



Source: Field, G., Color Scanning and Imaging Systems, GATF, 1990.

Look-up tables that are used to convert tristimulus RGB values of the original to their respective CMYK dot values are often generated using modified Neugebauer equations. In 1937 Hans Neugebauer *developed equations to describe the relationship between the RGB tristimulus values of the original and the YMC halftone dot values of the reproduction* [FIE90]. The equations devised by Neugebauer are shown in figure 3.15.

Fig 3.15 The Neugebauer Equations

$$R = (1-y)(1-m)(1-c) + y(1-m)(1-c)Ry$$
$$+ m(1-y)(1-c)Rm + c(1-y)(1-m)Rc + ym(1-c)Rym$$
$$+ yc(1-m)Ryc + mc(1-y)Rmc + ymcRymc$$

let:

Ry = red-light reflectance of yellow ink

Rm= red-light reflectance of magenta inn

Rc= red-light reflectance of cyan ink

Rym= red-light reflectance of the overlap of yellow and magenta

Rcy= red-light reflectance of the overlap of cyan and yellow

Rmc= red-light reflectance of the overlap of magenta and cyan

Rymc= red light reflectance of the overlap of yellow, magenta, and cyan

Source: Field, G., Color Scanning and Imaging Systems, GATF, 1990

G is substituted for R throughout the above equations for the green light reflectance, and B is substituted for R for the blue-light reflectance.

Ideally, it should be possible to print an accurate rendition of any colour by combining and printing the three CMY positives. In reality this is not the case, the three colours together define a gamut of possible colours that can be formed by combining them in varying proportions. Therefore there are colours outside the CMY printing gamut that cannot be printed with just three inks.

Also when the three subtractive primaries are printed together they do not produce a solid black, instead they deliver a muddy dark brown. This is a result of imperfect ink pigments and lack of ink density. Therefore a fourth black printer is added to increase the contrast of the greys and deep shadows, and other colours are reduced proportionately so that inks transfer properly on press.

To account for the black printer, Hardy and Wurzburg developed the four colour version of the Neugerbauer equations. Hardy and Wurzburg believed therefore that black ink alone had the same R, G, and B reflectance as black ink combined with any or all the other three inks [FIE90]. In other words:

$$Ryk = Rmk = Rck = Rymk = Ryck = Rmck = Rymck = Rk$$

Thus, the equation for red-light reflectance becomes:

$$\begin{aligned} R = {} & (1-y)(1-m)(1-c)(1-k) + y(1-m)(1-c)(1-k)Ry \\ & + m(1-y)(1-c)(1-k)Rm + c(1-y)(1-m)(1-k)Rc \\ & + ym(1-c)(1-k)Rym + yc(1-m)(1-k)Ryc \\ & + mc(1-y)(1-k)Rmc + ymc(1-k)Rymc + kRk \end{aligned}$$

Where:

k = black ink area

Rk = red light reflectance of black ink.

1-k = Area not covered by black

The green and blue versions of the equation can be obtained by substituting G and B for R.

Source: Field, G., Color Scanning and Imaging Systems, GATF, 1990.

To solve three equations for four unknowns, Hardy and Wurzburg specified that k equals the critical value for k, that is, the value that reduces at least one of the other three unknowns y,m, or c to zero. The critical value for k is computed by first solving the three-colour version of the equations and using the smallest of the y, m, and c signals to actuate a circuit that will supply a k signal to the equation-solving network just large enough to reduce at least one of the y,m, or c signals to zero.[FIE90]

Using the above Neugebauer equations as a means of generating look-up tables would not produce accurate colour reproductions mainly because of internal light scatter within the substrate. Therefore modifications to the original Neugebauer equations have been implemented in order to address the failings of the original equations.

Using Neugebauer equations instead of masking equations to generate look-up tables requires significantly longer computation to solve the equations. However, such computation is only required when important new ink/paper/press/ combinations are to be used to print the separations. Also the Neugebauer approach offers a "natural" method of colour display adjustment, which means that operator training is simplified

In many cases, colour separations are created directly from the original to film, without the data being stored on a hard disc or magnetic tape. When the image will be used just once, it is faster and cheaper to generate the separations directly from data rather than through an intermediate storage medium.

Most high-end scanners used today have the ability to generate the halftone dots directly, without a screen. They also provide finite control over frequency, angle, and spot function. Over recent years, the scanners have been combined with page layout stations so that all the elements of the page, including colour images, can be scanned at once, which reduces separation costs. Most scanners also provide built-in-control for two variables that significantly affect print quality: under colour removal and grey component replacement.

It would appear from the preceding information that the fundamental principles and techniques of colour reproduction are complex in terms of their operation and application. As a consequence of such complexity the application of desktop type computers to perform many of the functions associated with the reproduction of professional colour in any printed media has experienced significant problems over recent years.

4.0 Problems of Professional Colour Image Processing With Desktop Systems

Digital image processing in the graphic arts industry has always been characterised by the huge volume of data that requires manipulation and transmission to various prepress devices. The vast amount of data required for high resolution, pixel intensive images have traditionally been processed by proprietary systems designed for the purpose. The development of such systems inevitably led to expensive hardware and software solutions which prohibited simple interfacing between varying systems from a select number of competing manufacturers.

Through the latter period of the 1980s the continuing evolution of desktop publishing (DTP) systems employing widely available "off the shelf" microcomputer technology began to offer significantly cheaper solutions. However, despite the development of DTP solutions problems existed that inhibited their acceptance as a viable alternative for delivering professional levels of colour. The more significant problems that have arisen in the process of applying the desktop to perform many of the procedures associated with colour separation include: the moiré phenomenon, achieving colour matching, image compression and resolution, and other factors related to PostScript quality.

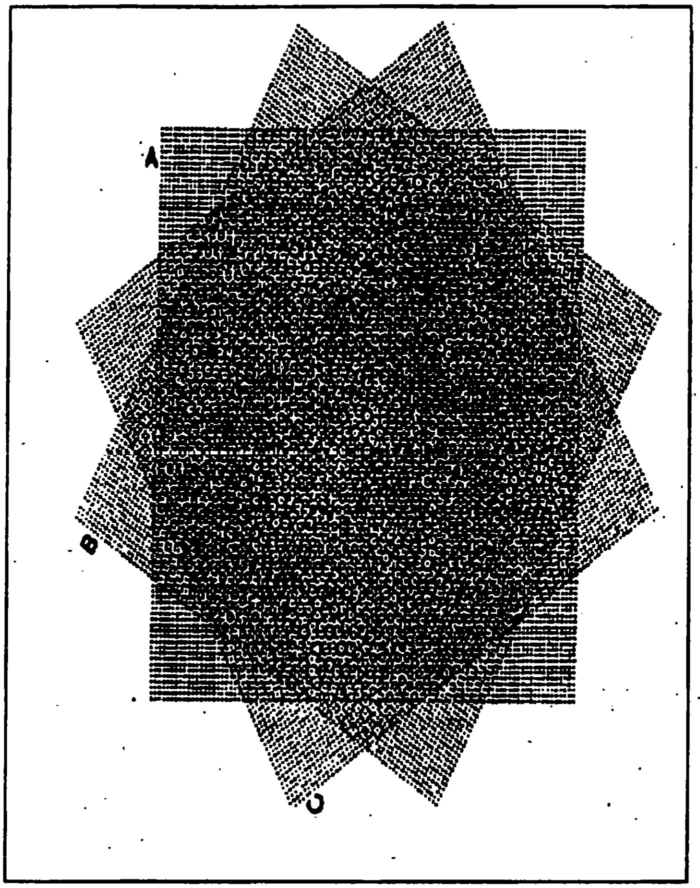
4.1 Desktop Colour Separation and the Moiré Phenomenon.

The increasing popularity of colour printing and its vast introduction into end-user desktop publishing has focused attention upon the moiré phenomenon. The moiré phenomenon consists of a visible pattern that appears to the eye when two or more sets of lines, grids or dot lattices are intersected although none of the original colour separated halftone films contains this "parasite" pattern. Unwanted moiré patterns may appear in the printing process for several possible reasons. For example if the original image itself is already halftoned, or contains some other fine periodical details, then a moiré pattern may be caused by an interference between the periodical fine details of the input image and either the input scanning frequency or the halftoning frequency. This type of moiré may already appear in black and white printing; but by far the most infamous moiré problem in the field of colour printing is the one which occurs due to the superposition of the halftone screens of the different process colours [AMI91].

In colour separation when the halftone dot lattices are superposed the intended result is a fine pattern of small dot clusters which can be seen even when no visible moiré patterns are present, see figure 4.1.overleaf. These tiny structure patterns are created by the combination of neighbouring dots from superposed lattices and are referred to as rosettes. However, when looking from a reasonable distance the eye can hardly distinguish the tiny dot clusters, and due to its spatial integration property, it integrates all fine details within each area of the superposed image into an impression of continuous colour and tone. The rosette pattern is derived from each of the colour separations i.e. CMYK being aligned at varying screen angles (see 3.2.3), so that when they are printed on top of one another they produce the desired rosette pattern.

The typical screen angles used in the graphic arts industry are shown in figure 4.2. overleaf. The reason why various screen angles are assigned to each of the process colours (CMYK) is that if all the colours are printed using the same angle and frequency, objectionable moiré patterns occur unless all of the 3 (CMY) or four (CMYK) passes through the press are in perfect register, a situation that is extremely difficult to obtain in practice. The choice of screen angles used in colour separation is based upon the principle that it is advisable to rotate the screen by 30 degrees (or 60 degrees if elliptical dots are employed) between two of the three primary colour separations, whilst maintaining uniform frequency . *When four primary colours are used it is normal practice to add the least dominant colour (usually yellow) somewhere in between at an angle of 15 degrees with one of the dominant colours* [MOL88].

Fig. 4.1. Rosette Patterns Derived from Separations Being Superposed over Eachother.



Source: Amidror, I., Raster Imaging and Digital Typography, p119,1991.

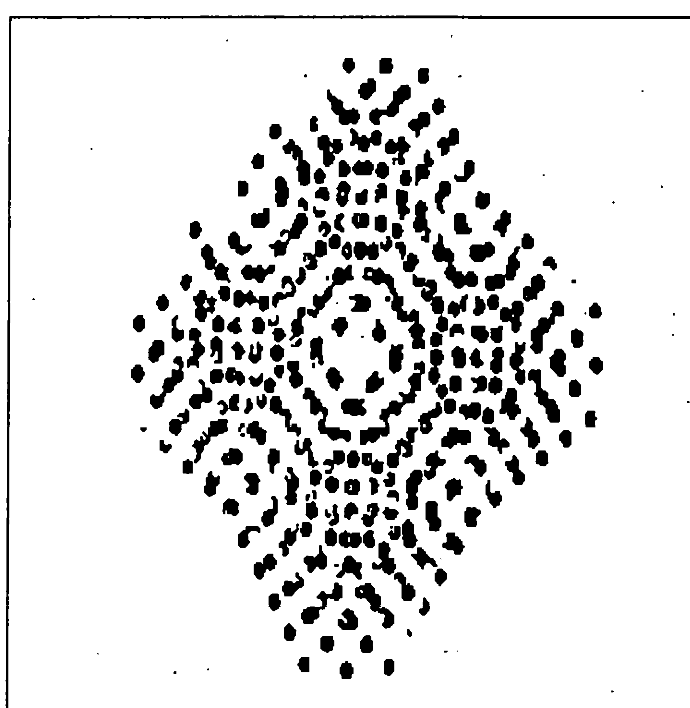
Fig. 4.2. Typical Screen Angles Used in the Graphics Arts Industry.

	K	M	C	Y
(1)	0°	30°	60°	15°
(2)	45°	75°	15°	0°
(3)	15°	45°	75°	0°
(4)	105°	45°	165°	0°

Source: Amidror, I., Raster Imaging and Digital Typography, p110,1991.

In digital colour separation the situation is quite different from the one outlined above. In traditional colour separation the only controllable parameters are the screen angles. However, in digital colour separation the screen frequencies can also be varied between the superposed screens. This in itself offers the possibilities of exploring moiré-free conditions, however, *the available choice of angles and frequencies is limited as the digitally produced halftone cells can only deliver approximations for given frequencies and angles (PostScript level 1 applications). Therefore a user may request a specific screen angle (e.g. magenta at 45 degrees) that is automatically converted into a close discrete approximation* [ROT88]. While this approximation is helpful in monochrome halftone printing where small deviations from the specified screen parameters can be tolerated, it may be disastrous in colour separation if each of the primary colours is approximated independently from the others resulting in hideous moiré patterns similar to those shown in figure 4.3.

Fig. 4.3. Moiré Patterns



Source: Amidror, I., Raster Imaging and Digital Typography, p119,1991.

4.2 Problems of Obtaining Optimum Colour Matching on the Desktop.

As computers get faster and cheaper, memories get larger, image manipulation and graphics programs become more sophisticated, and professional colour output devices become more readily available, the ability to work with high quality colour images on the desktop is becoming more practical. However, maintaining colour fidelity between the original and the reproduction is an elusive problem if one considers the multitude of different devices involved in the reproduction of colour on the desktop (see figure 4.4.overleaf).

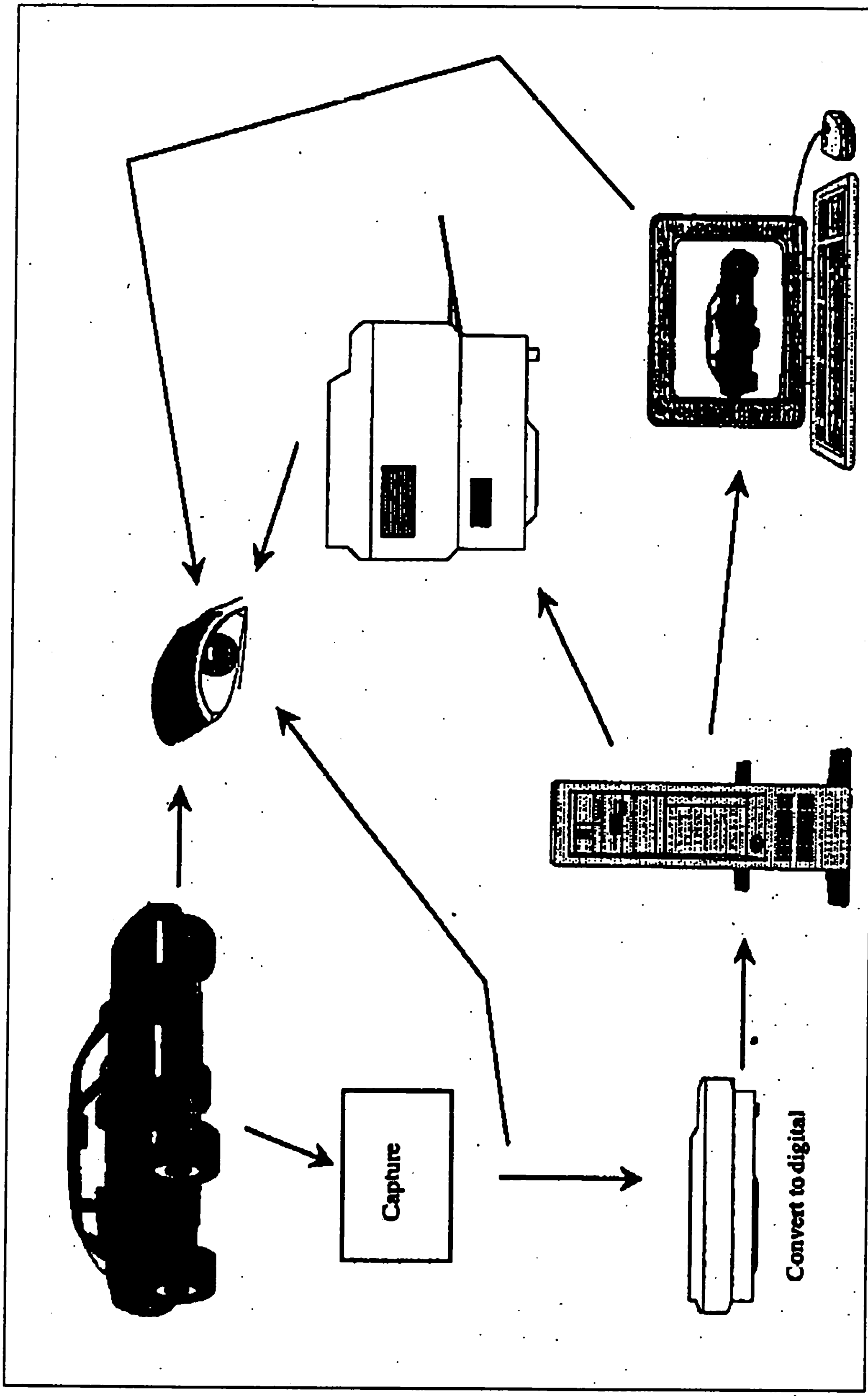
Each device will probably render colour in a different way and have a different colour gamut. Colour matching is a complex problem that requires as many as three separate calibration procedures for the three different stages involved:

Input: Obtain correct colour data from the input device (scanner).

Display: View the same colours the data intended on the monitor. The monitor must also simulate the colour temperature that is expected on output of the colour reproduction. The British Printing Industries Federation (BPIF) specifies a 5,000K colour temperature for its viewing standard.

Output: Match the colours of the output device (printer) to the colours of the original or the colours rendered on the monitor.

Fig. 4.4. Devices Used in the Reproduction of Colour.

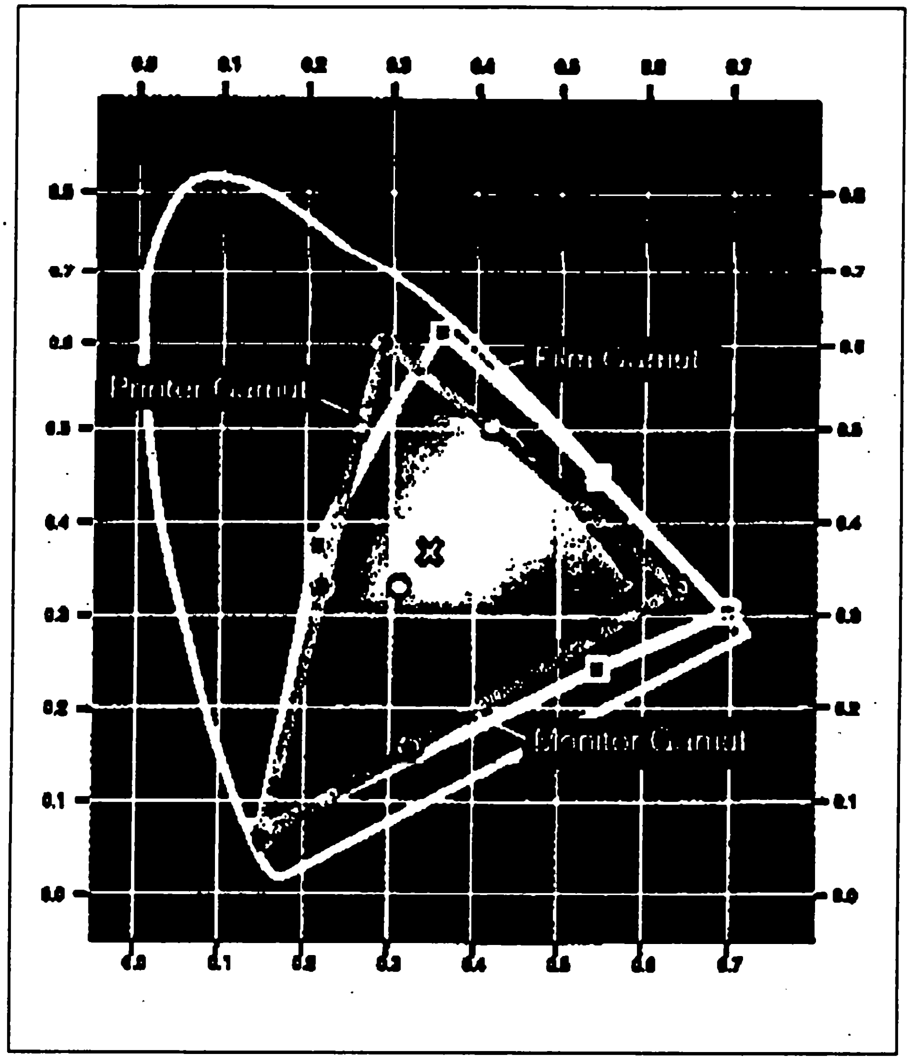


Souce: Kasson, J., An Analysis of Selected Computer Interchange Spaces, p 375, Oct. '92.

Obtaining uniform light (hue) between monitor and hardcopy is extremely difficult if one considers that the former is based on the principle of additive light whereas the latter is based upon subtractive light mixing that results in a variance in the overall light intensity. For example a yellow hue produced on a monitor will appear much brighter than the "same" yellow reproduced in a printed medium. This is a consequence of more emitted light entering the eye. It is also difficult to match saturations (spectral purity) between display and hardcopy. *Inks reflect a broader spectrum of light than phosphor emissions, and thus subtractive mixing always appears less saturated* [SOS91]. Mismatched colour gamuts always limit the fidelity of the colour match, and matching colour gamuts to monitors where different phosphors are used is always more difficult than matching display gamuts to printers. In relation to colour gamuts the overriding problem is *that no photographic medium or device, whether colour film or phosphor display or ink printer or other, can produce the full range of colours and tones that are perceived by the human eye. Unfortunately each device is determined by its primary colorants* [MAC93] (e.g. a monitor uses RGB as its primary colorants, printing uses CMYK as its primary colorants). These colour gamuts are usually represented as multi-coordinate bodies which differ according to device class (e.g. scanner, monitor, printer). These gamuts fall inside the gamut of all visible colours (see figure 4.5 overleaf). Therefore, *there are some colours that can be displayed on a monitor that cannot be printed and vice versa* [MAC93], and there are some real world colours that can not be reproduced using any class of device.

Each device used in the colour process may use a different colour model to render colour. Therefore an additional problem arises of conversion between the various models. Many factors, such as the nature of the input medium (film or paper), the temperature of the display, the ambient light, the type of inks used, and the substrate being used, can promote the difficulty of obtaining colour fidelity. As a consequence of this users are demanding open systems whose components communicate with each other through clearly defined interfaces. *To communicate colour unambiguously to* *many different devices, colours should therefore communicate colour in perceptual terms, rather than as recipes for particular devices to use to construct the colours* [KAS92].

Fig. 4.5. Various Colur Gamuts Falling Inside the CIE Colour Space.



Source: MacGilton , H., PostScript By Example, p539, 1992.

The selection of a conversion medium that is based upon the manner in which the human visual system perceives colours has led to the application of CIE colour matching systems. In implementing these systems a number of significant problems have, and continue to be encountered. The underlying principle of the CIE system is that two coloured samples with different colorants have the same XYZ tristimulus values. For example a blue produced on a monitor will have three values that correspond to the intensities of the three colorants used (RGB), whereas the "same" blue produced via printing will have three values that correspond to the three colorants used (CMY). Although the values for each sample differ the corresponding XYZ value for each is the same. Therefore they are perceived to be identical to eachother in terms of colour perception. However, *two samples with different colorants may have the same XYZ values under one illuminant and therefore give a visual match, but under a different illuminant they may have different XYZ values and therefore not match, a phenomenon known as* **metamerism** [MAC93]. Generally, the colours most likely to show the effect of metamerism are near neutrals. Metamerism occurs when relatively complex spectrophotometric curves are combined to produce a new curve. For example, it is possible to combine various proportions of green and magenta ink to produce a neutral grey under a given light source. Another grey can be prepared to match the first by mixing white and black inks. If the illuminant is changed the black-white grey will still be neutral, whereas the green-magenta grey will no longer be neutral [FIE92]. The CIE system is an excellent tool for defining the similarity between two stimuli under the same illuminant, but though the system can inform the user that the colours no longer match as the illuminant changes it fails to outline the actual appearance of the colours. Surround also plays an important part in the appearance of colour. In printing the surround is predominantly white paper, however transparencies are usually supplied with black surrounds. This can result in problems arising when a comparison is made between a transparency that has a black surround and a printed reproduction possessing a white surround. The transparency image with the black surround is perceived as having high contrast and brightness. Whereas the printed reproduction possessing a white surround, the perceived contrast and brightness are lower. *The influence of the surround not only depends on the colours of both the surrounded area and the surround, but distance has an influence, especially when trying to make comparisons between small originals and large reproductions or vice versa* [FIE92]. Simultaneous contrast effect and edge contrast are other factors that can influence the issue of maintaining colour fidelity. *Simultaneous colour* *contrast is the effect that occurs when colours that are identical appear different because of their different surrounds. Edge contrast occurs when two even tones that meet each other appear to have a higher contrast at the edge* [FIE92]. The result of this is that two samples of the same colour patches presented on identical media and with identical viewing media, even though they are measured to have identical XYZ values, will usually not match visually if the surrounds are different [MAC93]. Also systems that employ the metrics derived from the original 1931 CIE experiments such as Adobe PostScript level 2 are based on colour difference judgements using uniform fields of colour. *Relatively large uniform colour stimuli are rarely encountered in pictorial images* [STO92].

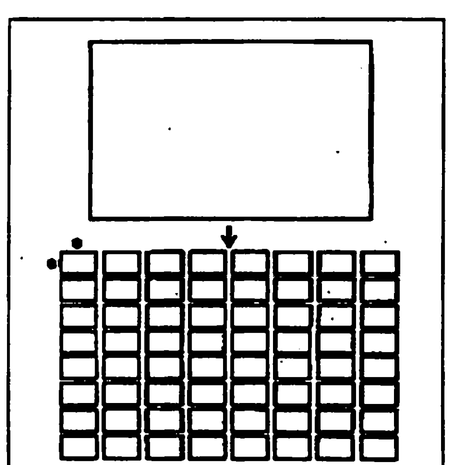
Other colour matching systems involve visually matching a known colour to a carefully printed standard such as Pantone, Focoltone, and Trumatch. The problem of using such systems on the desktop is that the original Pantone RGB specifications were obtained using a Mitsubishi monitor and therefore do not correspond to the popular Sony Trintron screens used on the Macintosh personal computer. However specifications that relate to Sony Monitors have since been applied. It is estimated that approximately 10 percent of Pantone inks fall outside a typical monitor's colour gamut, and as a consequence have to be approximated [SOS91]. Also, the specifications for Pantone are printed in a YMCK order, which does not correspond with the conventional CMYK order employed by many printers. All of the above factors result in subtle colour differences.

4.3 Problems Relating to Image Compression and Resolution

Resolution and addressability of a scanner significantly affect the quality of the image obtained. Higher levels of addressability (with a commensurate resolution) generally enhance quality. The penalty is an increase in scanning time and the volume of data collected. An optimised desktop system is one where the data volume is compressed by *an appropriate medium* [JOH91]. In selecting an appropriate compression medium the user is presented with a choice between a lossless or lossy based application. Examples of applications using lossless compression include StuffIt, ARC, and PKZip. Lossless compression produces a decompressed image that is identical, pixel for pixel, to the original image and therefore image quality is retained [ANS93]. The problem with lossless compression is that the attainable compression ratios on images are very small, typically 2 : 1. Therefore lossless based applications lack the compression "power" required for images manipulated in commercial prepress. Lossy compression methods in contrast are designed for image data that can achieve much higher compression ratios. The current standard in terms of lossy compression is the Joint Photographic Experts Group (JPEG) standard. The word "joint" comes from the fact that it was a collaborative venture between two standard commitees, the CCITT (International Telegraph and Telephone Consultative Committee) and the ISO (International Standards Organisation). The most widely implemented facet of the JPEG standard is the baseline Discrete Cosine Transform (DCT)-based sequential method. DCT-based sequential compression involves the following steps:

- *The image is broken down into 8 x 8 pixel blocks (see figure 4.6.) and each block is transformed via the (forward) discrete cosine transform (FDCT).*

Fig. 4.6. The Image is Divided Into 8 x 8 Blocks

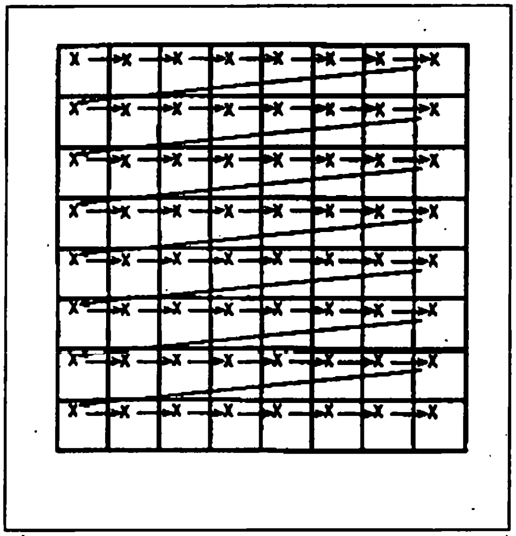


Source: Barnsley, M., Fractal Image Compression, p221, 1993.

* *The resulting 64 coefficients are quantized to a finite set of values. The degree of rounding depends on the specific coefficient.*

* *The DC term, a DCT coefficient representing the mean pixel value for each block, is differenced from the DC term of the preceding block in scan order (see figure 4.7).*

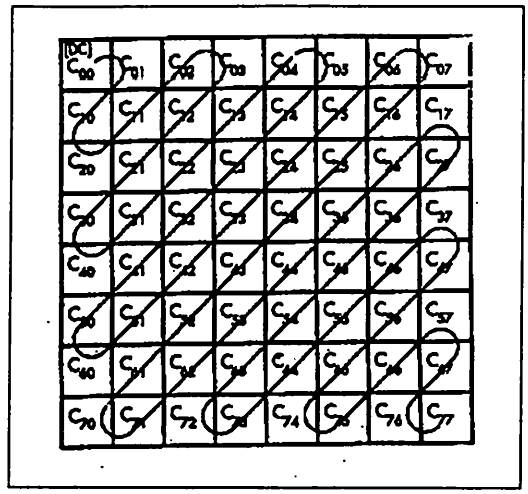
Fig. 4.7. <u>DC Coefficients (Block Means) are Differenced From Eachother in Scan Order</u>.



Source: Barnsley, M., Fractal Image Compression, p221, 1993.

* *The remaining 63 coefficients are scanned in zigzag fashion (see figure 4.8.overleaf). Each non-zero coefficient is encoded by the number of preceding zeros and its coefficient value.*

Fig. 4.8. The AC Coefficients are Encoded in ZigZag Order

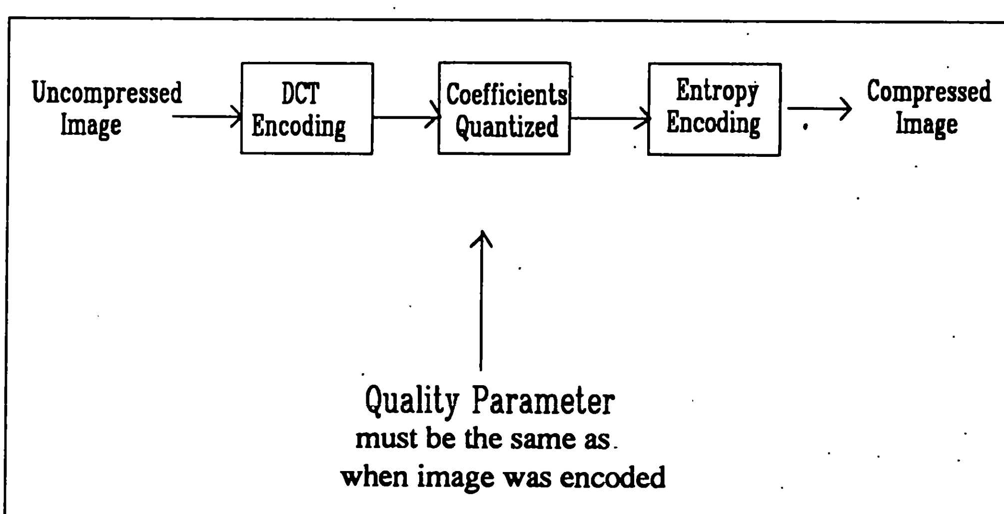


Source: Barnsley, M., Fractal Image Compression, p222, 1993.

- *The data stream is entropy-encoded by means of arithmetic of Huffman coding* [BAR93].

The above process is illustrated in figure 4.9.

Fig. 4.9. Stages in JPEG Encoding.



Source: Barnsley, M., Fractal Image Compression, p222, 1993.

Decompression is accomplished by applying the inverse of each of the preceding steps in reverse order. One starts with entropy decoding and proceeds to convert run lengths to a sequence of zeros and coefficients.

Although the JPEG method performs satisfactorily at lower compression ratios (upto 15 to 1) it suffers from serious problems at higher compression ratios. Since the first step in JPEG is to break the image into 8- by 8-pixel blocks, the compressed file is roughly proportional to the number of these blocks. Hence, as uncompressed files increase in resolution JPEG/DCT compressed files either increase in size or decrease in image quality. The JPEG assumption that higher frequencies are unimportant does not hold if the image has sharp edges. Extending the higher frequency DCT-basis functions results in effects such as unwanted ripples spreading from the edges, called *Gibbs* phenomenon [ANS93].

The most serious problem caused by the long term use of JPEG compressed images is that they are resolution dependent. Therefore, any attempt to display the compressed image at a higher resolution than the original will result in visible pixel blocks that are a consequence of pixel replication.

The quality issue is much more important in prepress than in other applications using the JPEG standard. The default parameters proposed by JPEG are inadequate at meeting the quality criteria demanded by prepress users. Such inadequacies result in unacceptable artifices if any but the smallest compression ratios are used on images with a high degree of detail [HIL93].

4.4 Problems Related To PostScript Quality.

There are a number of specific issues that affect PostScript's ability to perform high quality colour work. The more significant issues include:-

Speed- PostScript has experienced a substantial amount of criticism regarding its speed in processing complex colour work, if one considers that digital image processing in the graphics arts industry has always been characterised by the large volume of data that requires processing, (an A4 four colour image contains approximately 36 MBytes of data at 300 lines per inch with 32 bits per pixel resolution [JOH91]). These resolutions have been shown by experience to be necessary for image quality levels expected by the graphics arts industry. For many of the "usual" image processing algorithms, mathematical complexity is not particularly high (although there are noticeable exceptions to this) but even relatively simple algorithms can create substantial bottlenecks in a system because of the need to move relatively large data volumes from memory to CPU and back. Therefore, high-end systems have processed colour work using boards especially designed for the purpose linked to one another by high bandwidth proprietary buses which enabled rapid transfer of the data. By running these processes serially but concurrently, high bandwidths are obtained; these are frequently only limited by access times achievable with the mass storage devices on which the data was held. Although mini computers were generally used for controlling file handling and some processing, CPU speeds combined with expensive memory only enabled them to be used for very limited image processing tasks. However, through the latter period of the 1980s and early 1990s a number of developments combined that significantly promoted PostScript solutions as viable alternatives. Cheaper memory and mass storage combined with higher speed processors have significantly increased the data processing which may be achieved using "off-the-shelf" desktop workstations that incorporate PostScript. However, despite these developments some of the problems described above still exist. Whilst PostScript awaits the introduction of "off-the-shelf" parallel processors, CPU speeds act as a bottleneck particularly when images require a series of processes to be applied which cannot be convolved mathematically [JOH91].

Productivity- Productivity from PostScript isn't just a function of the speed of the raster image processor (RIP), but involves the overall infrastructure of the system. To be fully productive *PostScript colour systems need to be configured with print servers that provide high data security*, throughout the responsiveness. It is pointless being able to print a page out in ten minutes if the Macintosh that originated it is still tied up. System configurations for high resolution colour also require a range of publishing services software modules to perform functions such as file format conversions, automatic replacement of view files, and checking for runtime errors prior to sending files for processing [PFE92].

Transparency- PostScript is an opaque imaging model that deposits pixels and "forgets" their origin, thereby allowing it to drive output devices without much disk storage or memory. Transparency, however, presumes knowledge of both existing pixels and their origin, as well as new pixels coming into the RIP. This is particularly problematic when combining new and existing pixels in a halftone, for example. Handling the latter is very compute intensive, and thus requires lots of disk space or memory. An additional concern centres upon what proportion of the internal pixel state the user saves for future rendering versus casting data off to make memory available for incoming data [HAH92].

Trapping- The traditional solution to registration of images in prepress is a technique known as trapping, in which one colour is expanded (*spread*), while another is contracted (*choked*), so the images "fit" together. However, trapping is very device dependent, making its implementation using PostScript applications a major software engineering problem.

Vignettes- PostScript does not handle vignettes efficiently. A vignette is a graded tint area on a page with systematic and continuous colour variation. The simplest form of vignette is a rectangular area, with two colour specifications at the extremes, and a smooth transition in between. Technically vignettes require sophisticated generation methods. On output the addition of some *noise* is required to avoid banding or the appearance of graduated steps in the colour variation. PostScript does not have a description mechanism for vignettes. Therefore DTP PostScript applications break up vignettes into a large number of small bands [WOO93].

It can be seen that the application of desktop type technology to perform many of the functions associated with the colour prepress process has experienced a number of significant problems over recent years. However, it will become evident later in the dissertation that since the inception of desktop publishing a variety of emerging solutions have been developed and applied that strive to resolve the problems described earlier.

5.0 Current Solutions Offered Within the Colour Desktop Environment

Ever since Paul Brainard of the Aldus Corporation introduced the phrase "desktop publishing" or DTP in 1985, a plethora of emerging solutions have been developed and applied in an attempt to resolve the problems associated with the rendering of professional colour described earlier. The more significant colour solutions which have emerged include: colour matching/management systems, screening solutions that strive to eradicate the problem of the moiré phenomenon, and other periphery solutions oriented towards the elimination of other problems described earlier.

5.1 Colour Matching/Management Solutions.

To anyone involved in the accurate reproduction of coloured images using a variety of devices it is readily apparent that colour imaging is an area of intense, rapid technological development and an area that presents many challenges and opportunities. One such challenge arises from the need to ensure that users across the prepress environment (ranging from internal office users to high-end professional printing services) can communicate colour in a common manner that provides consistency and accuracy in the reproduction of colour in the printed medium.

Colour matching is of particular importance considering the evolution of the open system environment in the prepress process. It is essential that colour images which are communicated from user to user, site to site or device to device resemble the colour(s) envisaged. Meeting this challenge will require new applications for managing and specifying colour in a device and application-independent manner.

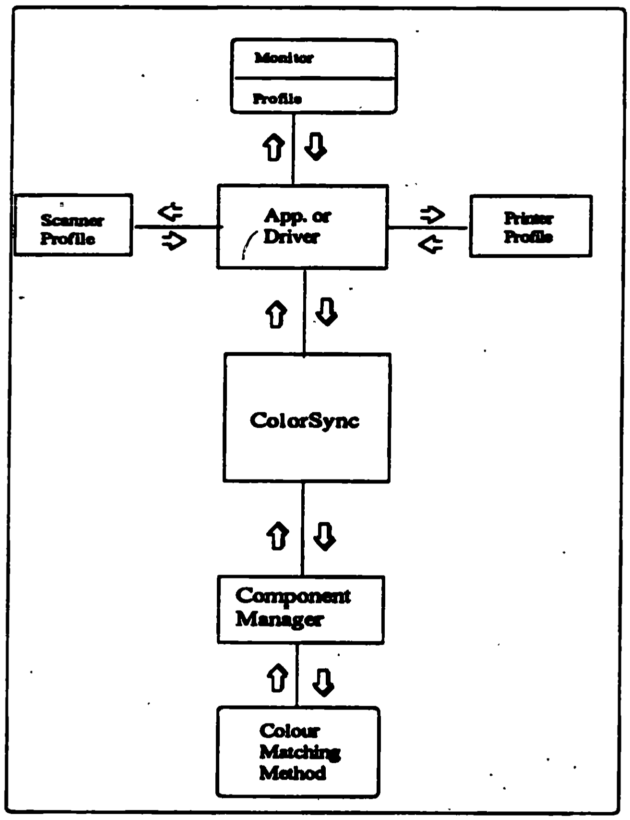
Many of the colour management systems available or being developed today offer centralised colour calibration services, i.e., they collect device profiles, provide a central repository of the data relating to device profiles and perform the conversion for individual devices (usually in the host computer). In contrast to these centralised colour management systems, Adobe has chosen a distributed approach in PostScript level 2 wherein conversion is performed in the device itself. Thus any device based on PostScript level 2 does not have a built-in colour space. Rather they support whatever colour space is needed. Level 2 delivers the data into that space so the conversion can be performed in the device itself. Performing colour space conversion in the device itself can be a compute-intensive task that effectively reduces processing speeds by approximately two to one. However, Dr James King of Adobe believes it is preferable to off load the conversion process from the host computer and have the time consuming process performed in the rendering device instead [SEY92c].

5.1.1 Examples of Colour Management/Matching Systems.

Apple ColorSync- Apple's ColorSync is a system level colour management tool that provides basic colour matching capabilities as well as a framework on which third parties can build more sophisticated and specialised colour management tools. ColorSync provides an extension to QuickDraw that essentially redefines its underlying RGB model in a device-independent sense and uses the CIE.XYZ reference space instead (see 3.2.2). It is intended to provide device-independent colour support at the system level so that it is possible to move a file or an image from one device to another while maintaining consistency and colour fidelity within the range of the device's capabilities. It is intended also to provide an open architecture upon which software vendors may contribute other value-added updates, ranging from full colour management systems to very specific calibration programs.

Beyond functioning as a framework upon which software vendors can develop more specialised colour matching systems (see figure 5.1 overleaf), ColorSync can also function as a base-level colour management implementation for mass market users. It includes a device-profiling methodology embedded in individual drivers or the applications that supports them, as well as in automatic default colour-matching methods requiring no operator intervention. Another convenient user-oriented feature is a gamut check that can actually be generated on the output device specified. In addition, ColorSync lets the user preview an image by displaying it in the colour space of the output device (or medium) on the monitor [SEY92c].

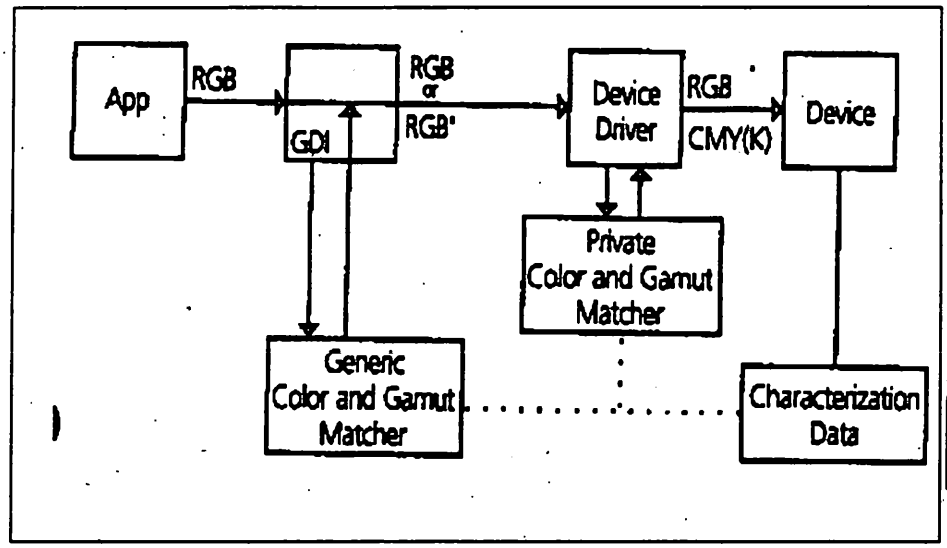
Fig. 5.1. The Apple ColorSync System.



Source: Seybold, J., The Seybold Report on Desktop Publishing, Vol. 7, No. 3, p21, Nov.'92.

Microsoft Colour Management System- At the system level, Windows defines a colour space against the CIE.XYZ standard and allows for colour communication between different devices and applications. It characterises what a device is capable of and calibrates colour values accordingly. Device colour information is then embedded in the Windows device-independent bitmap format. MicroSoft are adopting a similar approach to Apple in that the system alone is intended for mass-market "off the shelf" users, while providing the basic architecture upon which software vendors can develop more specialised colour matching facilities [SEY92c](see figure 5.2).

Fig. 5.2. The MicroSoft Colour Management System.



Source: Seybold, J., The Seybold Report on Desktop Publishing, Vol. 7, No. 3, p22, Nov.'92.

EFIColor- Electronics For Imaging technology consists of two modules. The processor provides the colour-matching methodology and a series of individual device profiles. The Cachet colour correction module includes EFIColor management technology and provides a way to edit colours "by reference" to others that already have the appropriate values assigned to them to bypass the issue of What You See Is What You Get (WYSIWYG) colour on the display. EFI also provide a gamut alarm that shows on the monitor display what colours cannot be printed by an individual device before the user sends the file off. It also allows the operator to use the display to simulate the colour reproduction capabilities of the intended device such as a proof printer or press.

EFI have also introduced a scheme for tagging colour image files with a tag that identifies which colour space was used when the image was created. This is a simple, yet immensely powerful, concept. A page may contain several images, each created by a different program, or even on a different system using a different colour space. Rather than converting them to a common colour space (and perhaps, reconverting them one or more additional times as the page is moved through the production process), each can be carried as it was created without conversion and transformed into another colour space only when necessary for screen display or final output [EFI93].

Linotype-Hell - Linotype's new colour management system addresses the three critical colour-matching tasks: input calibration, monitor calibration and output-device-dependent print space adaptations. The Linotype products use the CIE-LAB colour space internally and combine CIE-lab look-up tables with other Linotype-Hell tools and devices for device characterisation (i.e. find out what a device can do) and calibration (match colour values).

Input- For calibration of RGB scanners, Linotype-Hell is using the Kodak Q60 test target in conjunction with a special tool kit that measures RGB input values and approximates CIE.LAB equivalents. These values are compared against Q60 ideal measurements and custom look-up tables are generated to map the RGB-input device values into the internal colour model using the Macintosh Colour Transform Unit (CTU). The CTU is a NuBus card that functions like the colour computer of a high end scanner.

Display/Image Manipulation- In terms of monitor calibration the Linotype system can be operated to show RGB independent of print conditions, or they can simulate the CMYK values of the proposed output device on screen.

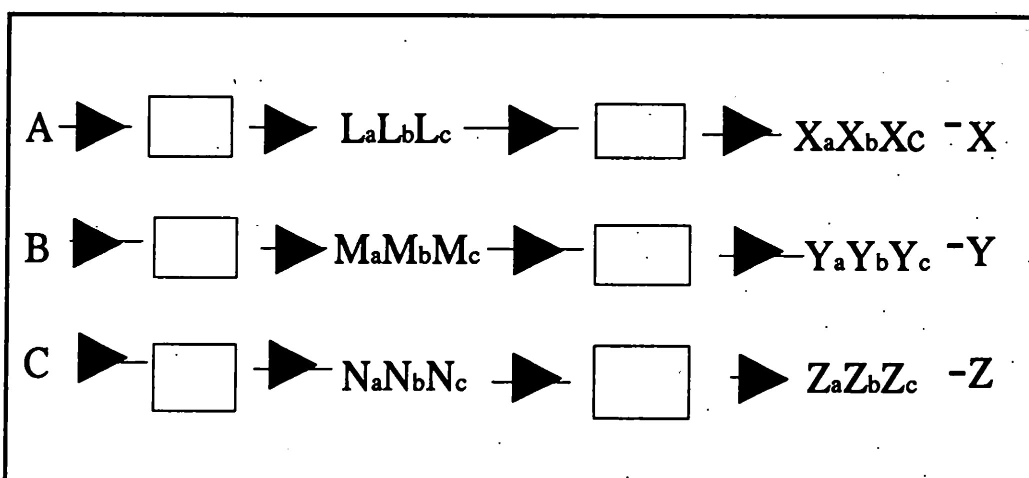
Output- After colour editing, Linotype's output print space adaptation generates output transforms adapted to the specific output device or process. This requires a print process calibration (PPC) procedure that uses a description print target to identify the colour space of the individual output device (e.g. proof printer or printing press). The characterisation of the output device encompasses gamut printing process, ink or colorants, paper substrate, etc. The PPC is printed on the device and then subjected to spectrophotometer analysis in order to generate appropriate CIE.LAB values. These CIE.LAB values that characterise the output device are stored in a look-up table with the known CMYK values from the film that produced the PPC target. Individual images are then transformed by looking at the CIE.LAB data in the table, and comparing and interpolating as needed to derive CMYK output [SEY92c].

It can be ascertained from the information above that the Linotype-Hell colour management system is heavily dependent on the implementation of CIE.LAB values. The underlying principles of the CIE.LAB are outlined in 2.2.2.

Agfa FotoFlow- Based on the CIE colour space and using the IT standard references for both transmissive and reflective materials, FotoFlow is a collection of device independent products available for Macintosh and PC platforms. FotoFlow depends on accurate device characterisation and colorimetric gamut processing to create algorithms for transforming colours with fidelity from the reference space into and out of device specific spaces. The device profiles (or ColorTag as Agfa refers to them) describe the device's colour behaviour. The ColorTag records the colour device's colour gamut, and automatically compensates for colours that lie outside the device's colour gamut using an appropriate algorithm. Also the Agfa system allows ColorTags to be "chained" together into a ColorLink, which translates colours from one device to another [AGF92].

4.1.1.6 Adobe PostScript Level 2- PostScript level 2 support for colour matching is based upon CIE's XYZ colour space (see 2.2.2). As described earlier in 5.1 the Adobe approach to colour management is that the conversion is performed in the device itself. Thus any device based on PostScript level 2 does not have a built-in colour space. Rather they support whatever colour space is needed. PostScript level 2 solutions are able to support the colour space needed by the implementation of the **CIEBasedABC** operand that encompasses a number of related colour spaces (listed in *The PostScript Language Reference Manual, Second Edition, Addison-Wesley Publishing 1991*). The **CIEbasedABC** operand activates the setcolorspace dictionary which describes how to map from the colour space being used to XYZ colour space. This mapping is defined by two warp functions and two matrix multiplacations. Figure 5.3. illustrates how a hypothetical colour space ABC is mapped to XYZ respectively.

Fig. 5.3. Hypothetical Mapping of Colour Space ABC to XYZ Respectively.



Source: MacGilton, H., PostScript By Example, p507, 1992.

The transform is carried out in two identical stages, which allows the user to map an intermediate colour space (represented by components L, M, and N) before mapping to XYZ. The letters A, B, C, L, M, and N do not have any special significance, they simply denote hypothetical components in the user's colour space. Each stage of the transformation consists of a warping stage, which allows the user to apply a non linear transformation to each component of the stage individually, followed by a linear transformation that transforms from one set of components to another [MAC92]. The transformation algorithm has many parameters, including an optional, full three dimensional colour lookup table. The colour fidelity of the output depends on these parameters being properly set, usually by a procedure that includes some form of calibration. Each product includes a default set of colour rendering parameters that have been chosen to produce reasonable output based on the nominal characteristics of the device. The PostScript language does not prescribe procedures for calibrating the device or for computing a proper set of colour rendering parameters [ADO91].

5.2. Screening Solutions.

Ever since colour arrived on the desktop, system developers have strived to emulate the colour achieved using expensive high-end traditional systems. One of the major difficulties associated with the implementation of the desktop has been hideous moiré patterns that occur as a consequence of inaccurate screening during the colour separation process (see 3.1). The application of rational supercell technology and Frequency Modulated (FM) screening has to a large extent eliminated the problems associated with moiré described earlier in 4.1.

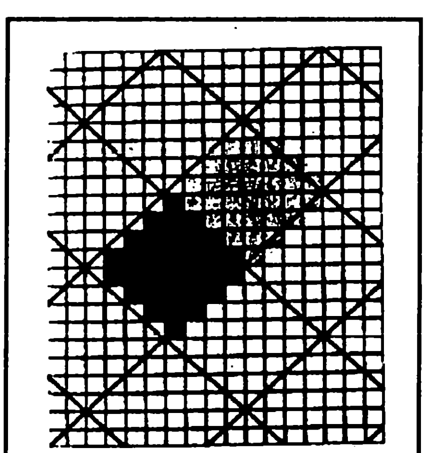
5.2.1 Rational Screening Technology

In understanding Rational Supercell Technology it is important to consider rational angles (i.e. capable of being expressed exactly by a ratio of two integers) and irrational tangent angles (incapable of being expressed exactly by a ratio of two integers). Halftone screens are placed over device space consisting of a regular grid of pixels. Halftone cells should intersect with device space consistently so halftone cells should contain the same number of pixels (as in figure 5.4. overleaf). Note that each corner of the halftone cell corresponds exactly with the corner of a pixel, and each cell encompasses the same pattern of device pixels. Rational tangent angles produce halftone screens that ultimately intersect with device space in a consistent manner. So the halftone cells are identical and the rendering machinery can calculate one master cell and replicate it over device space [MAC92]. Irrational tangent angles produce halftone screens that never intersect with device space consistently. Hence, master cells cannot be computed and replicated consistently. This unfortunate situation is addressed using two different approaches.

- substitute the nearest rational tangent angle for the requested irrational tangent angle, and adjust the frequency accordingly.
- use the irrational tangent angle, and calculate each halftone cell individually[MAC92].

The latter approach produces high quality results but requires intensive, time consuming computation and is typical of the approach adopted by high-end rotational drum film recorders. So lower end rendering devices such as those based on the PostScript typically substitute a rational tangent angle and adjusts the frequency accordingly. This is the reason why users do not always get the angles and frequencies requested. Sometimes this angle substitution produces moiré patterns and as a consequence Adobe and others have developed a series of rational supercell technology solutions.

Fig. 5.4. The Intersection Between Device Space and the Pixels of Digital Halftone Cells.

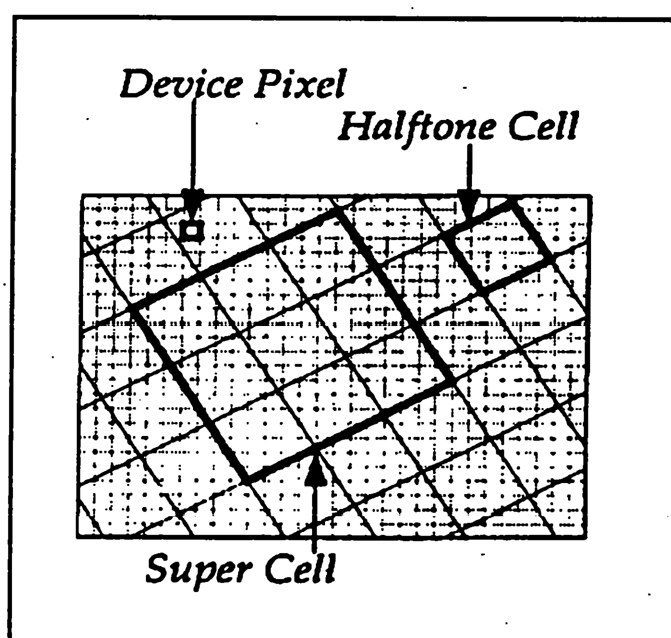


Source: MacGilton, H., PostScript By Example, p537, 1992.

Examples of Rational Supercell Technology solutions

Adobe Accurate Screens(AAS)- AAS takes a new approach to laying halftone cells over device space. Previously, the corners of every halftone cell had to correspond exactly with the corner of a device pixel, essentially limiting the choice of angles available. Accurate screens increase the choice of angles and consequently increase the accuracy of the angle achieved. Using accurate screens technology, the halftoning machinery constructs *supercells* consisting of many halftone cells. Therefore, only the corners of the supercells have to correspond with the corners of the device pixels. The position of the individual halftone cell's corners no longer matters. This method of constructing halftone cells is referred to as the *supercell technique*. Figure 5.5 illustrates a supercell that is three halftone cells on each side. Each supercell aligns with device pixels, but individual halftone cells do not. Supercells use rational tangent angles but create a large enough moiré period to be less objectionable. Accurate screens are precise but computationally expensive, so they are normally turned off. However, the user can explicitly turn accurate screens on when specifying halftones via the halftone dictionary mechanism **/ AccurateScreens true def** [ADO91].

Fig 5.5. Adobe Accurate Screens SuperCell Technology.

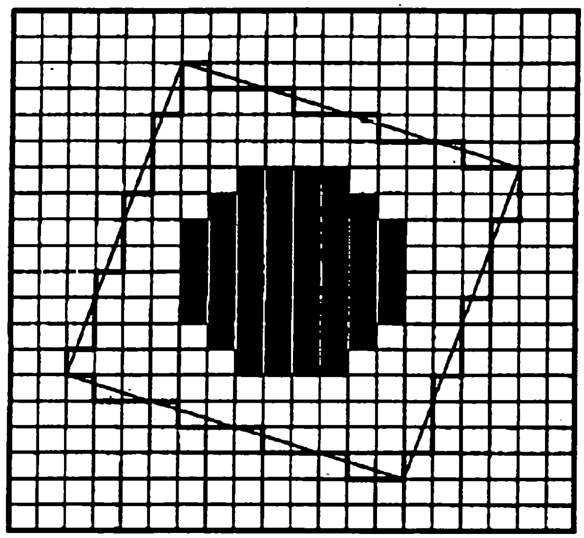


Source: Adobe Systems Inc., Adobe Accurate Screens Technology Handbook, p6, 1992.

Agfa Balanced Screening (ABS)- In order to maintain screening performance, Balanced Screening takes a unique approach to digital screening known as screen precalculation. Other PostScript screening technologies consist of mathematical algorithms that reside on the raster image processor (RIP). During screening, the RIP must calculate the appearance of each four-colour screen at a given resolution and frequency "on-the-fly". These calculations require considerable processing power and can significantly degrade performance. Instead of requiring on-the-fly calculation, ABS technology consists of complete precalculated screen descriptions that are downloaded to the RIP. Screen precalculation accomplishes two goals: it improves performance by removing the burden of processing off the RIP; and permits far more refined screen descriptions than on-the-fly calculations [JEN91]. ABS includes a software filter that enables the user to configure the system quickly for each job. During screening, the software filter intercepts the screening set-up of the software application being used and substitutes the ABS specifications. The user simply specifies the resolution and screen frequency required. ABS is available in a software format that makes upgrades much easier than replacing hardware RIP upgrades. ABS is also compatible with all PostScript Level 2 applications.

Linotype-Hell High Quality Screening (HQS) Screening Solutions- Linotype-Hell introduced the HQS algorithm as a software upgrade to their RIP 30 in mid-1991. HQS screening has been widely used on high-end colour prepress systems for a number of years, however it is now available for PostScript output devices. With HQS Screening, the ideal screen angles are calculated to a precision where any deviation only affects the fourth decimal place value. HQS uses up to 3000 screen cells simultaneously to determine the screen angle. This is known as the *Linotype-Hell Supercell* [LIN93]. The basic mechanism underlying the HQS principle is shown in figure 5.6. overleaf.

Fig. 5.6. The Linotype-Hell HQS Screening Mechanism.



A single screening cell is set at an angle of 18.4° instead of 15°. HQS Screening calculates on the basis of a supercell, which can consist of up to 3000 screening cells.

Source: Linotype-Hell Ltd., Us Screening with PostScript so Mysterious?, p5, 1992.

5.2.2 Frequency Modulated (FM) Screening

Both Rational Supercell Technology and Irrational Screening are conventional, amplitude modulated screening mechanisms. In the case of an amplitude modulated screen, the amplitude, or size of each halftone cell is varied by grouping together device pixels to represent varying cell intensities. However, the frequency, or spacing between the cells is kept constant. Under FM screening the amplitude, or size of dot remains constant, however, the spacing between the dots is randomized in to order to vary the average intensity. *Normally the spacing of the dots is arranged to be integer multiples of the standard dot size* [CRO94]. Experience suggests that high quality imaging requires small dots to be distributed carefully to ensure smooth results with minimal patterning. The distribution or spacing of the dots, although controlled on average by the image level, is controlled at the low end by a randomizing process which tries to avoid any visible artifacts. FM screening algorithms are now much improved in comparison with those used originally. Such improvements have now made it possible to produce better quality results at lower expose scanner resolutions than those used for conventional halftone screening.

Although the basic principle of FM screening is relatively straightforward, the technique used to avoid visible artifacts is more complex.

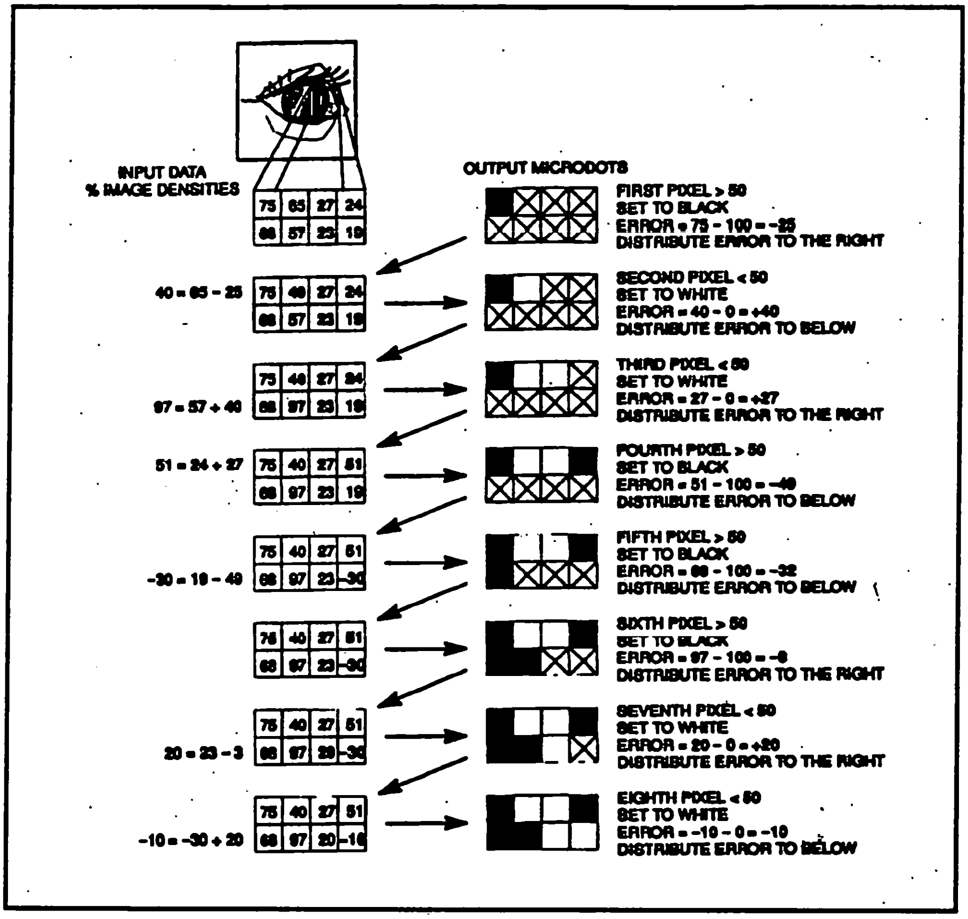
A digitized page or image comprises data values representing the density for each of the four colour components in a pixel, where the pixel size is determined by the input scan resolution. Each input pixel has a density value varying between 0 and 100% which in practice is normally represented as a byte with 256 available levels. When the page or image is processed for output on a device using FM screening, the pixel size becomes the size of the FM dot and is therefore the FM screen resolution, and each dot is made either 100% density, or 0% density which is a space.

As each pixel in the page or image is processed, a decision is made to make the output dot either 100% or 0%. This decision is made by a data value threshold. For example, if the input data is above 50% the output dot is made to be 100%, if it is less than 50% it is made to be 0%.

Implementing the above would result in a very rough posterized version of the original input. FM screening therefore employs an additional technique to calculate the output data of 0% or 100% and the input data, and then distribute the error to the surrounding input data that has yet to be processed. This makes the threshold output dependent not only on the current original data but also on the previously processed data. This ensures that the area covered by the dots corresonds exactly to the average density of the input data and so provides a good representation of it [CRO94].

The diagram shown in figure 5.7. demonstrates the error distribution and thresholding for a region of eight pixels. It uses a very simplistic algorithm where the whole error is either distributed to the right hand pixel or to the one immeadiately below choosen at random. In practical terms this would not produce good results and is only used here to demonstrate the basic principles.

Fig. 5.7. Principle of FM Microdot Distribution.



Source: Crosfield Electronics Ltd., Lazel Screening Tech. Manual, p3-7, 1994.

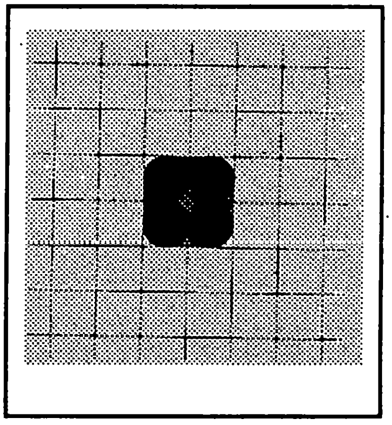
Succesful FM screening is determined by the technique used to distribute the errors to the surrounding pixels. Firstly, the error must be distributed randomly to avoid any visible pattern. Secondly the errors should be distributed such that their effect are localized to their point of origin, otherwise large scale visible patterns can occur. This can be achieved by distributing the errors among several surrounding pixels but with the largest amount being distributed near the point of origin.

Examples of FM Screening Applications.

Linotype-Hell Diamond Screening- Diamond Screening is offered as an option on their PostScript RIP 50 and RIP 60 processors in the form of software upgrades. Linotype Hell anticipate that the performance of Diamond Screening will be enhanced by utilising the processing power of the RIP 60 XPO and the TurboPix accelerator incorporated within their PostScript RIP 50. Linotype-Hell intend Diamond Screening to complement rather than replace their existing HQS and I.S. technologies as each technology has its own advantage.

Linotype-Hell recommend using *Diamond Dots* with a 20 µm which can be output in two resolution/dot combinations using the Herkules imagesetter and R3020 PS/R3030 PS repro recorders in combination with RIP 60 XPO. If the Herkules images at 500 pixels/cm, the diameter of the dot corresponds exactly to the 20µm (1cm : 500 = 0.02 mm = 20um). However, 20µm dots can also be generated by clustering 2 x 2 dots of diameter of 10um and a resolution of 1000 pixels/cm (see figure 5.8.). The dot produced is not round but is almost square with rounded corners. Other cluster formations available at various resolutions are shown in figure 5.9. overleaf.

Fig. 5.8. Linotype's *Diamond Screening* Clustering Mechanism.



Source: Friemel, E., FM Screeening: Reliability in Production, Deutsche Drucker, Issue 46, Dec.'94.

Fig. 5.9. Cluster Formations Available with *Diamond Screening*.

The generation of Diamond Dots	Resolution	Diameter of Diamond Dot	Clustering
	1333 pixels/cm	15 µm	2 × 2 pixels
	1333 pixels/cm	30 µm	4 × 4 pixels
	1000 pixels/cm	20 µm	2 × 2 pixels
	1000 pixels/cm	40 µm	4 × 4 pixels
	666 pixels/cm	15 µm	1 × 1 pixels
	666 pixels/cm	30 µm	2 × 2 pixels
	500 pixels/cm	20 µm	1 × 1 pixels
	500 pixels/cm	40 µm	2 × 2 pixels

Source: Friemel, E., FM Screeening: Reliability in Production, Deutsche Drucker, Issue 46, Dec.'94.

When clustering round pixels whose diameters are equivalent to one imaging step, the contact between each is only slight. The resultant triangles and the diamond shape in the centre are not imaged. *The fact that a square cluster is generated with round corners is a result of the light cones undergoing a Gausian distribution. Two light cones overlap eachother at half height, close the triangles and the central diamond shape and generate an almost square dot* [FRI94].

If the text quality permits, Linotype recommend that imaging should be performed with a lower resolution and a correspondingly smaller number of diamond dots in order to accelerate imaging. Imaging speeds of Diamond Screening at various resolutions are shown below in figure 5. 10. The greater the number of small diameter dots to be imaged at high resolution in each square centimeter, the higher the dot gain will be since the colour overlap extends to all the dots [LIN93].

Fig. 5.10. *Diamond Screening* Processing Speeds at Various Resolutions.

Resolution	Processing Speed.
500 Pixels/cm	52cm/min
666 Pixels/cm	39cm/min
1000 Pixels/cm	26cm/min
1333 Pixels/cm	13cm/min

Source: Friemel, E., FM Screeening: Reliability in Production, Deutsche Drucker, Issue 46, Dec.'94.

Linotype-Hell also strongly recommend that Diamond Screening should be used in conjunction with hard dot *Kodak 2000 series* films, which are claimed to provide significant advantages (see 6.2.2).

Crosfield Lazel Screening- Lazel Screening is available as an option on a wide range of Crosfield imagesetters including MagnaSetter 750, MagnaSetter 2000 and MagnaRip. Existing MagnaSetter and MagnaRip users can upgrade, adding Lazel Screening to the MagnaDot Screening Technology. Crosfield Lazel Screening has within it a calibration feature that *fingerprints* the dot gain characteristics of the imagesetter and the printing process. The dot positioning system in the RIP, it is claimed, avoids mottling whilst using printable-size dots that still maintain high levels of quality. The calibration process has three steps: 1. Precision laser power setting to ensure optimum dot exposure; 2. Patented dot overlap compesation algorithms; 3. Tone curve linearisation ensures consistent dot gain on the press. Lazel Screening primarily uses the following dot resolutions:

- 24l/mm (609 l/i) 42μm dot.
- 36l/mm (914l/i) 28μm dot
- 48l/mm (1219l/i) 21μm dot

As regards film, Crosfield recommend that Lazel screening should be used in conjunction with DuPont HDB4 film and HCD/R processing chemistry that together are designed to produce a hard dot output with a maximum logarithmic density of 5.5. Crosfield like Linotype-Hell are offering Lazel Screening as a complementary option to their existing conventional screening mechanisms.

Agfa Cristal Raster- Cristal Raster is available as an upgrade option on Agfa Cobra RIPs driving a SelectSet imagesetter. In terms of film processing Agfa naturally recommend using Agfa GS 712 HN films in conjunction with their G101 and G333 film processing chemicals for optimum results.

5.3 Image Compression Solutions

As described earlier in 3.3 the conventional JPEG compression technique suffers from a number of limitations that have created difficulties in implementing it within graphic arts environments. However, modifications of the standard JPEG algorithms have to some extent addressed the limitations associated with the JPEG technique.

Highwater Designs have modified the standard JPEG algorithm in order to meet the stringent levels of image quality that prepress demands, whilst retaining sufficient information to show virtually no recognisable degradation after screening. The result of such modifactions is the CH-JPEG compression technique. As mentioned earlier (see 4.3.) JPEG compression is based on time consuming *Discrete Cosine Transformation* calculations that, without adaptation, have proved prohibitive. The CH-JPEG compression therefore uses a specially devised algorithm that limits the calculation time required. The algorithm itself is impemented on a *i960* board *that allows a degree of parallelism in implementaion within the processor itself, and further parallelism in that input and output of data take place independently of the processing. The result is compression scheme that while being slower than a JPEG dedicated hardware solution is acceptably fast and fits in with other processes such as scanning* [HIL93].

Highwater advocate that their system allows the prepress user to enjoy the benefits associated with image compression (i.e. reduced disk storage and faster transmission of files) without having to sacrifice image quality. CH-JPEG is available as a software option or on a *i960* board for accelerated processing. Both options allow image data to be compressed to less than a tenth of it's original size [HIG93].

PicturePress is a compression application from Storm Technology targeted at professional users. It allows the user to manipulate the variables controlling the JPEG algorithm. Therefore, the user can customize the quantization tables for chrominace and luminance, choosing independent vertical and horizontal subsampling rates and generate Huffman-encoding tables, which compress more data, albeit at slower speeds. By controlling the amount of quantization applied to the chrominance and luminance, acceptable quality with higher compression rates can be achieved than would otherwise be possible. For example, an image with little contrast but a wide range of colours can lose more luminance data and less chrominance data than high contrast image in which a few tones predominate.

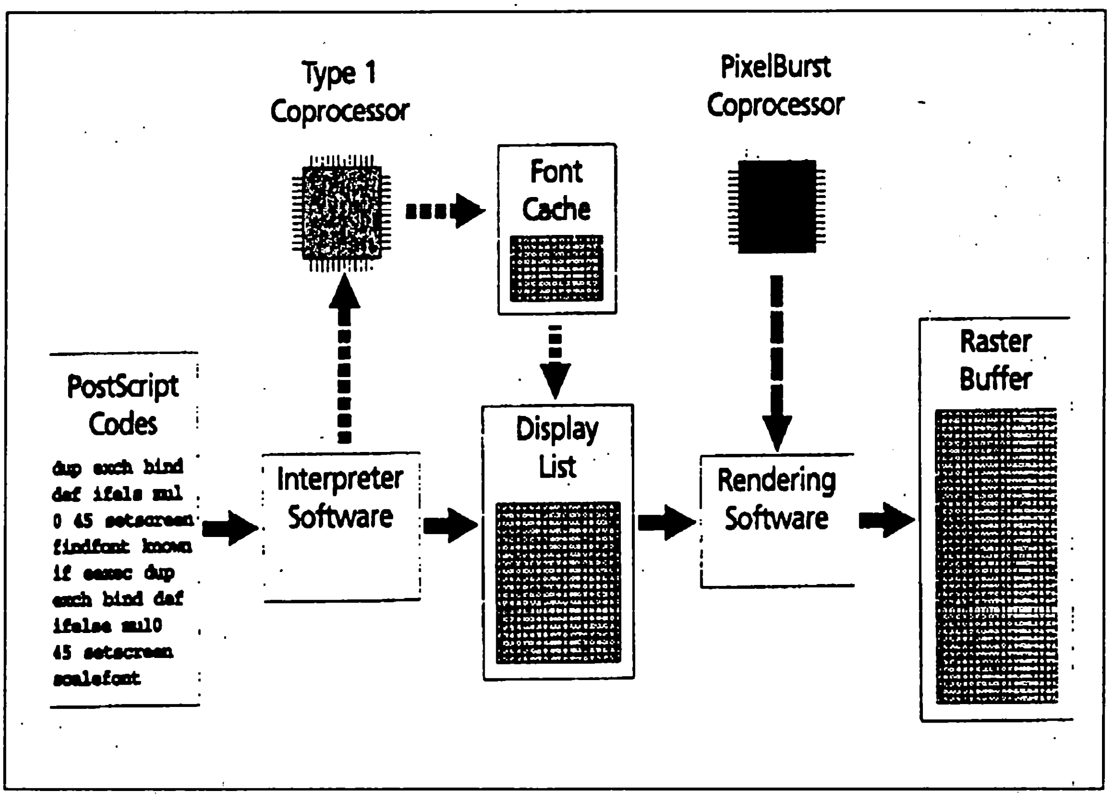
Another possible solution to the inadequacies of JPEG compression is selective compression. Selective compression is built into the JPEG++ specification in PicturePress. Under selective compression the user can assign lower compression ratios (and hence better image quality) to segments of the image that contain the area of interest, while higher compression ratios are used for segments of the image that contain less important elements. This technique could be employed in catalogue type work where the product being advertised could be less compressed (higher quality) than the background image [KIE91].

5.4 Additional Periphery Solutions

As described earlier in 3.4 there are a number of specific issues that affect PostScript's ability to perform high quality colour work. However, two recent development have striven to eliminate the problems associated with speed and trapping. Adobe's PixelBurst chip has to an extent addressed the issue of PostScript speed, and Aldus's TrapWise has resolved many of the difficulties encountered in trapping colours.

Adobe PixelBurst Chip- The work of a PostScript interpreter typically comprises several tasks. It begins with decoding the incoming stream of human-readable PostScript commands; this involves fetching fonts from the disk and building the dictionaries, stacks, paths and other data structures in the controllers memory. The result of this is a display list: a sequence of primitive drawing commands for trapezoids, clipping masks, contone images, character bitmaps for text and so on, all sorted by their respective positions on the page. The display list then has to be converted into an array of bits at a specific resolution. This is where the PixelBurst chip comes into effect. Each bit represents one pixel, or printer dot, in the page image, and will be used to turn the laser on and off when the page or film is output. The process involves lots of low level bit-manipulation. When this is performed in software, it takes many clock cycles for each bit. However, PixelBurst performs these low level bit- manipulations in hardware using a five stage pipeline to process multiple pixels on each clock cycle. Using a 33-MHz clock, and given an optimum memory configuration, Adobe, claims that PixelBurst can fill shapes at sustained rates of 900 million pixels per second [SEY92a]. The role of the PixelBurst chip in the rasterizing process is shown in figure 5.11.

Fig. 5.11. The Role of the PixelBurst Chip in the Rasterizing Process.



Source: Seybold, J., The Seybold Report on Desktop Publishing, Vol. 7, No. 2, p39, Oct.'92.

PixelBurst also performs halftone screening in hardware, at rates upto 100 million pixels per second. It uses whatever screening method, angle, frequency and spot function are specified in the PostScript command file. If Adobe's Accurate Screens function is enabled, the chip will use that screening technology. PixelBurst is also compatible with other screening algorithms offered by other vendors. In addition, the chip offers an optional error-diffusion algorithm that reduces the banding that often appears in vignettes (see 3.4).

The PixelBurst chip itself is a display-list rendering coprocessor containing an Application Specific Integrated Circuit (ASIC) that has around 60,000 gates. The chip is designed to operate autonomously for large fractions of time. It has its own memory access circuitry, allowing it to read the display list and write out the raster bitmap without any assistance from the RIP's main processor. This means that while PixelBurst is rendering a page, the host processor can begin working on the next task.

With a suitable direct memory access (DMA) controller, the PixelBurst chip could share the RIP's main memory, thereby saving some money. Because the two processors will often be in contention for access to the RAM, neither processor is likely to be able to run at full speed. However, like a math's chip, the PixelBurst has its own instruction set (i.e. the Adobe Display List) and contains an internal ROM that knows how to decode and execute those instructions. It thus puts less of a load on the system bus than would a second CPU, which must constantly fetch instructions as well as data across the memory bus.

Overall in terms of speed Adobe's in-house tests show that, depending on the job, the speedup for screened images using PixelBurst can be as much as a tenfold increase in comparison with modern Reduced Instruction Set Computing (RISC) software RIPs. Higher-resolution output will benefit more than low-resolution output such as text and line art which has generally experienced a twofold speedup[SEY92a]. The PixelBurst chip will be made available to PostScript licensees who are developing their own accelerator boards.

Aldus Trapwise2- It is now possible to trap and to print colour separations using TrapWise 2. The program can trap up to 16 colours at once, more specifically four process colour inks and twelve spot colours. Trapwise is also able to trap continuous tone images, hairline rules and vignettes. In addition line art can be trapped as vector art for applications that include bar graphs and pie charts. TrapWise automatically creates traps by employing a software RIP that is based upon the work carried out by Graphic Edge which translates PostScript files into a proprietary format. TrapWise then examines every edge on a page, determining if a trap is required, then positions and colours each trap for minimum visibility. Notably TrapWise is able to trap line art over continuous-tone images. Those trapping instructions, which are built as a series of PostScript commands, are then output with the original file. Processing speeds depend on page complexity. Aldus claims that an average page takes fifteen minutes [SEY93]. TrapWise is available on Mac, Windows, and Unix platforms and is compatible with applications that conform to Adobe Document Structuring Convention (DSC) 3.0.

It is evident that a number of solutions have emerged since the inception of DTP that have attempted to emulate the quality of colour fidelity delivered using conventional high end digital colour systems. However, it is important to asses the viability of these solutions by critically appraising current debates concerning DTP/prepress developments discussed in related articles and papers

6.0 Current Debates Concerning Desktop Publishing/ Prepress Developments.

The continuing evolution of desktop publishing has given rise to a number of eminent writers regularly publishing their opinions on the most recent technological developments. Their opinions can often influence the prepress community as to the viability of such developments. Therefore, a critical appraisal of their most recent discussions becomes imperative in order to establish the validity of current colour solutions (described in chapter 5), as well as identifying current research trends oriented towards the successful reproduction of colour.

6.1 Current Debates Concerning Colour Matching Schemes.

In attempting to establish an open system that specifically addresses the issue of colour matching/management on the desktop a number of solutions have emerged as potential candidates. Therefore it is imperative to appraise these solutions and their underlying technology by analysing current debates that relate to the issue of colour matching/management.

6.1.1. Appraisal of Current Colour Matching/Management Solutions

It is readily apparent from the solutions outlined in 5.1.1 that the colour matching capability of an application is reflected by its intended market. The nature of the market encompasses not only the price of an application but also its performance, ease of use, and other considerations. This in itself has resulted in vendors targeting different sections of the market.

Apple and Microsoft have essentially targeted the lower end of the colour matching market by concentrating on system level solutions that provide rudimentary colour matching facilities which satisfy the needs of mass market users. However, it is evident that their main function is to act as platforms upon which other vendors can supply more specialised colour matching facilities. This notion is supported by the fact that EFI's EFIColor, Kodak's KCMS, and Agfa's AutoColor and FotoFlow are compatible with one or both of the system-level platforms [SEY92c].

Agfa have taken a different approach by developing and applying their own colour matching solution, as opposed to licensing the technology of another vendor (e.g. EFI or Kodak etc). By developing their own proprietary solution Agfa obviously envisage that the colour management market will expand rapidly in the near future. Agfa is adopting an open approach employing more resources with the clear intention of increasing its market penetration.

Linotype-Hell in contrast are embarking on a much more insular approach as its colour matching software is not being offered independent of the Linotype system [SEY92c]. As Linotype have traditionally concentrated on the high end of the colour prepress market the introduction of proprietary colour matching software suggests that Linotype are unwilling to change their marketing policy.

Adobe's approach to colour matching using PostScript Level 2 is that it downloads the task of colour transformations from one space to another to the individual rendering device, and can therefore work in conjunction with any of the colour management/ matching systems. Adobe therefore maintains that colour data transformation is best performed in the output device (i.e. a PostScript Level 2 device). Clearly then Adobe are advocating the implementation of rendering devices that licence PostScript Level 2 technology which is obviously advantageous to Adobe.

EFI are approaching the issue of colour matching/management in a unique manner in that the colour conversions are only processed prior to the final output using the EFI Metric ColorTag specification. This addresses the key issues of speed and quality in that the number of colour conversions that need to be made is significantly reduced, which drastically speeds up the entire process as colour conversions require intensive and time consuming calculations. Also conversion calculations involve some form of round-off error [SEY92c] which results in loss of colour information, and therefore a loss of quality. Particularly if these conversions are performed using 8- bit rather than 12- or 16- bit colour data. Stokes et al suggest that for precision colour using the CIE.LAB colour space 9.7 bits are required in the L dimension and 10.5 bits for the a & b dimensions, and in the CRT RGB colour space 9.7 bits per channel are required [STO92]. The EFI approach represents a significant shift from the conventional desktop method of matching colours whereby specifications and the manipulation of coloured images are performed early in the process. The approach adopted by EFI was supported by a panel of vendors and users whose opinions on colour matching were outlined in The Seybold Report on Desktop Publishing. The panel concurred *that all of the device dependent variables, including colour space conversion, calibration to the output device, ink and paper, CMYK colour separation, under colour removal, grey component replacement, screening and trapping, should be performed as a final step by automatic software that has full knowledge of the final output process* [SEY92c]. Also the panel concurred *that future colour prepress systems should work with device-independent colour* [SEY92c].

6.1.2 Appraisal of Device Independent Colour (CIE)

It was concurred by The Seybold panel of vendors and users *that future colour prepress systems should work with device independent colour*[SEY92c]. Recent applications oriented towards colour matching on the desktop are based upon the principles of device independent colour. The concept of device independent colour was developed by the Commission Internationale de l'Eclairage (CIE) in 1931. The performance of CIE, or one of it's derivatives (e.g. CIE.LUV and CIE.LAB) in relation to its colour matching capability has and continues to be the subject of extensive research and debate.

The underlying objectives and principles of the CIE system have previously been described (see 3.2.2). The rationale behind implementing the CIE system within prepress devices and systems is that:

> *For a colour reproduction system in which each pixel of an image is measured according to the CIE method, and is made to produce the same tristimulus values when reproduced, it may be expected that a colour match will result. What will have been achieved may be described as colorimetric equivalence* [JOH92].

However, a number of debates in recent years have challenged the validity of employing device independent colour solutions to provide colour matching facilities within the graphic arts industry. It is generally recognised that device independent colour systems will only deliver a reproduction in which the colours appear to match exactly if a variety of constraints are adhered to [MAC93]. Such constraints include:

- Both the original and the reproduction posses the same XYZ tristimulus values for their respective white points;

- the two samples (i.e. original and reproduction) have similar surface characteristics and are observed under similar viewing conditions;

- the reproduction is able to deliver all of the colours that are contained within the original image [JOH92].

Johnson [JOH92] and MacDonald [MAC93] maintain that adhering to the above constraints is not practical in a conventional prepress environment as the factors outlined above differ considerably from device to device. They also argue that the successful implementation of device independent colour within graphic arts is dependent upon resolving the following problems.

Differences in White Points- In a situation where the original contains a brighter white than the reproduction is able to attain, the question arises of how the brighter white of the original is rendered in the reproduction. A widely accepted solution to the problem of white point differences is to reproduce *lightness relative to the white point for each* [JOH92]. Therefore, the image data of both the original and the reproduction are normalised to their respective white points. Engaging this "correction" technique also addresses minor differences in colour between the white points. However, if the differences between the white points of the original and the reproduction are sufficiently large then the above correction technique fails.

Differences in Device Gamuts- Probably the most significant problem relating to device independent colour is that every device employed within the prepress process is limited by the colorants it uses to render colour. The colorants used (e.g. RGB, CMYK) determine what colours can be rendered by the device, i.e. its colour gamut. Colour gamuts are usually represented as multi-coordinate bodies in which the colorants used to render colour are the parameters of the gamut, and all colours which can be produced using combinations of these colorants falling inside these parameters (see figure 4.5). Therefore, the situation arises whereby *some colours can be displayed but not printed and vice versa, and there are some real world colours that cannot be rendered using any device* [MAC93]. Therefore, there is a need to apply techniques that perform gamut compression for all devices from input through to final output. Implementing gamut compression techniques requires the selection of an appropriate interchange colour space as well. MacDonald [MAC93] suggests that the more common gamut compression techniques involve implementing one of the following strategies:

Truncate -Any colour that lies outside the gamut of the rendering device is substituted by the closest colour value that the gamut can provide. The substitution colour selected is therefore usually situated on the gamut's boundary.

Umbrella - All the colours that are contained within the original are scaled in a linear fashion so that they fall within the gamut of the rendering device.

Non-linear - This strategy involves the scaling of colours that reside near the boundary of the rendering device's gamut as opposed to scaling all the colours contained within the original.

Image Dependent - This strategy is reliant upon a skilled device operator adjusting the colour editing facilities of the device in order to maintain consistent colour fidelity between original and reproduction.

Monitor Gamut "Compression"- This technique involves moving the chromacities of the three phosphors (RGB) towards the monitor's white point. The rationale behind this technique is that the phosphors are de-saturated (i.e. containing more white light) resulting in a higher level of ambient light, thus giving a more "natural" appearance. However, such a technique fails to recognise that people regularly view images on different monitors anyway.

Xerox Gamut Compression Algorithm- The objective of the Xerox technique devised by Maureen Stone is to maintain the appearance of the image by *fitting the source (display) image gamut to the destination print gamut* [MAC93]. The Xerox algorithm involves transforming every pixel of the display image into their respective CIE.XYZ values. *Then mapping the grey axis via translation, scaling and rotating from source* *to destination device, and finally reducing colour saturation by an "umbrella folding" of values around the neutral axis* [STO88].

Conventional Gamut Compression Techniques Within Graphic Arts- Traditional gamut compression within graphic arts involves the manipulation of lightness, hue, and chroma (LCH). The Hue is preserved whilst the lightness element is compressed linearly, in order to accommodate variances in surround conditions. Also the chroma element is compressed linearly. However, adopting the above compression techniques is still a limited solution in that it is only appropriate for certain types of work. The compression technique can be improved *by mapping the distribution of colours towards a centre point on the lightness axis (i.e. a neutral grey), obtained by averaging the minimum and maximum values in print* [LAI87]. The successful application of this correction technique is reliant upon:

- the perceptual uniformity of the colour space in which the gamut mapping is performed;

- the colour gamuts used should have similar shapes;

- the print gamut should be totally confined within the gamut of the original [MAC93].

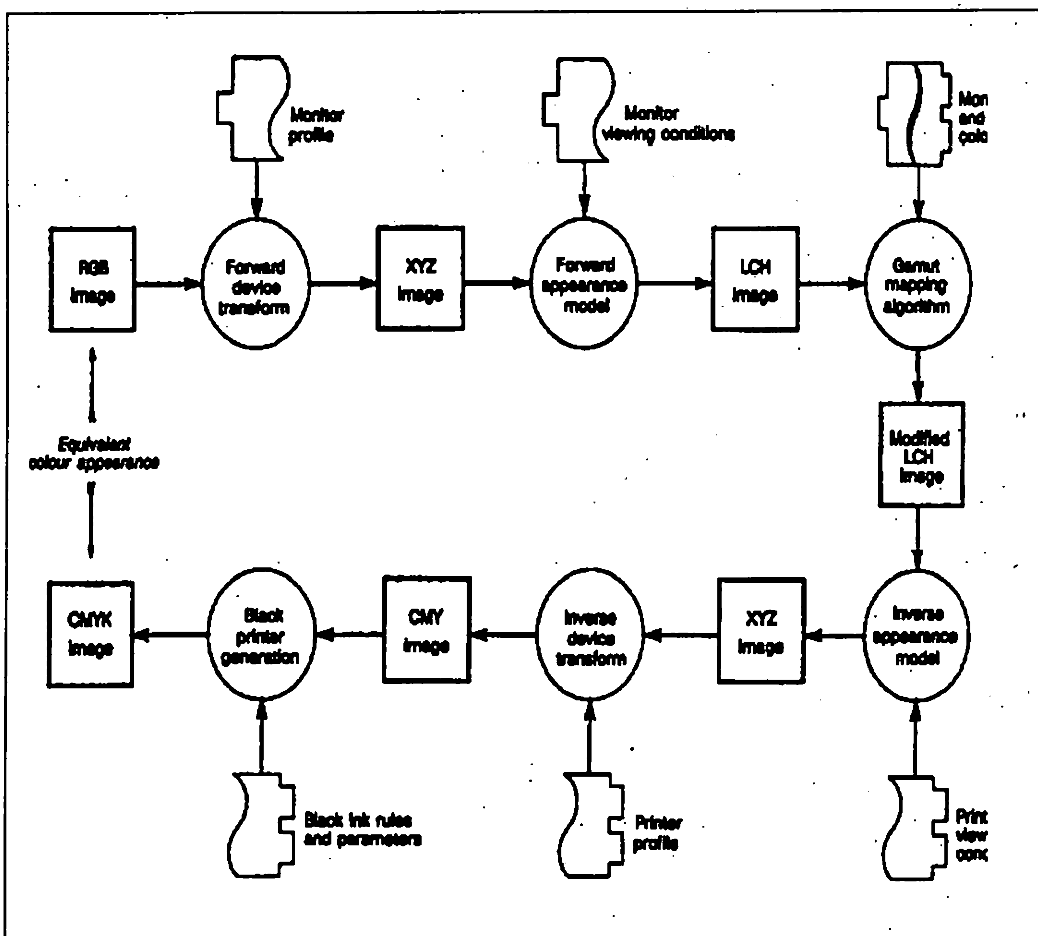
<u>Differences in Measurement Instrumentation.</u>- Device independent colour is based upon achieving colorimetric equivalence which in turn depends upon the accurate measurement of colour using standard instrumentation e.g. Colorimeters and spectrophotometers. Colorimeters deliberately eliminate first surface reflections whereas spectrophotometers are designed to totally include first surface reflections. However, conventional viewing conditions cannot simulate either situation and so colours that appear to match in a practical environment may measure differently using such instrumentation [JOH92].

Differences in Viewing Conditions- The implementation of colorimetric equivalence as a means to obtaining a colour match between the original and the reproduction is only effective if both have similar surface characteristics and are viewed under similar viewing conditions. Therefore as viewing conditions change the colours contained within the original and reproduction no longer match even though their XYZ tristimulus values are identical, a phenomenon known as metamerism. However colour models are being devised (principally by Robert Hunt) that resolve this problem [JOH92]. Another factor that relates to viewing conditions is the effect that surround can have on the appearance of colours (e.g. yellow on a black background will appear lighter than an identical yellow printed on a white background). This illustrates a further weakness of device independent colour, however, colour spaces are currently being devised to address this problem.

Johnson [JOH92] and MacDonald [MAC93] conclude that device independent colour which is reliant upon the doctrine of obtaining colorimetric equivalence cannot be freely applied within graphic arts until the differences outlined earlier are resolved. However, MacDonald in his work on *gamut mapping in perceptual colour space* advocates the use of a five stage transform that attempts to address the limitations of device independent colour using correction techniques that are based upon colour spaces devised by Dr Robert Hunt. Also it is important to note that Johnson has also been involved in the development of these correction colour spaces through his participation with Dr Robert Hunt in the CARISMA project (Colour Appearance Research for Interactive Systems Management and Applications). Therefore it is believed that it is vital to appraise these correction colour spaces in order to establish whether the failings of device independent colour outlined by Johnson and MacDonald have been resolved.

It is apparent from the discussions of Johnson and MacDonald that the three stage transform from input signals (RGB) into a colorimetric colour space (CIE.XYZ) and thence to the destination output signals (CMYK) is limited in its application. Therefore, MacDonald maintains that the three stage transform should be extended to a five stage transform involving the inclusion of Hunt's LCH (light, chroma, and hue) colour appearance space. *In this space gamut mapping can be performed in an optimal manner* [MAC93]. The operation of the five stage transform devised by MacDonald is shown in figure 6.1.

Fig. 6.1. MacDonald's Five Stage Transform.

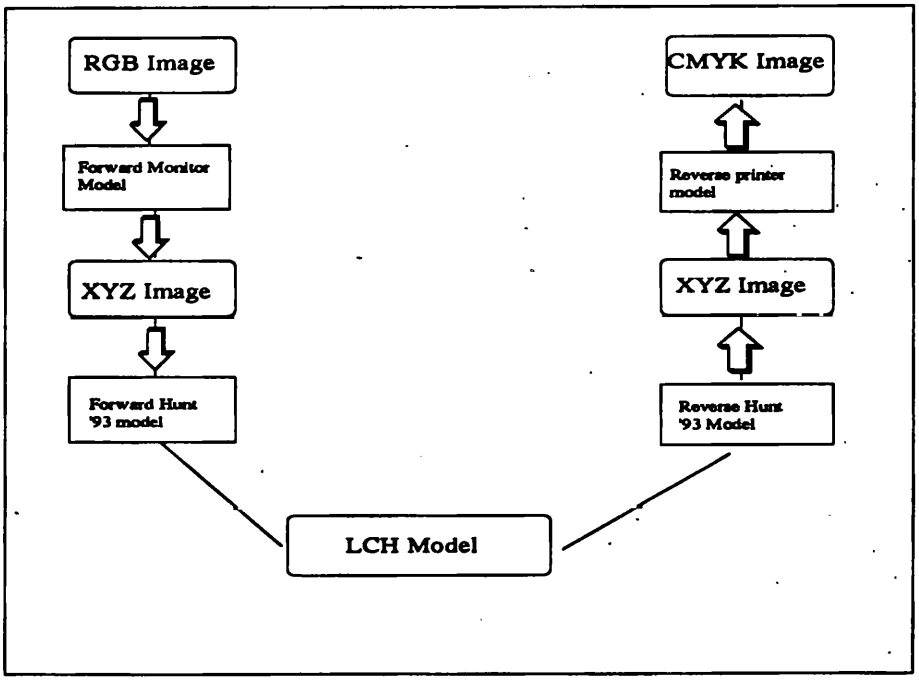


Source: MacDonald , L., Gamut Mapping in Perceptual Colour Space, Nov.'93.

In figure 6.1. the first stage of the transform involves converting the RGB image into XYZ via the monitor profile data derived from the previous characterisation. The resultant XYZ is then converted into perceptual LCH coordinates by using the colour appearance model, taking into account the parameters that define the monitor viewing conditions. The LCH image can then be manipulated to take account of variances between monitor and printer. The modified LCH image is then converted using the inverse colour appearance model back into XYZ via the parameters that define target print viewing conditions. This resultant XYZ image is converted into the final CMY ink values via the printing device profile data and a black ink (K) value is derived from CMY by means of constraints imposed by parameters such as the degree of grey-component removal [MAC93].

Also it is important to consider that Hunt's LCH 1993 colour appearance model has been applied in the ColourTalk system. The ColourTalk system was derived from the findings of research carried out as part of the Alvey project. According to Dr Ronnie Luo, the Alvey project leader, the Hunt 93 model can *now consistently predict colour appearance as well as a typical human observer. This performance is considered to be highly satisfactory and the model is therefore believed to provide an accurate way of evaluating various colour reproduction systems* [LUO92]. The ColorTalk system is based upon a *four stage transform*. The mechanics of the four stage transform are shown in figure 6.2.

Fig. 6.2. The ColourTalk Four Stage Transform.



Source: Luo, R., Effective Colour Communication for Industry, p518, Dec.'92.

Initially, the monitor image (defined in terms of RGB) is converted pixel by pixel, into an equivalent XYZ image using the monitor calibration method. Secondly, this XYZ image is then transformed by the Hunt '93 model to obtain an LCH image, where LCH are perceived attributes under the monitor's viewing conditions. Thirdly the LCH image is converted to an XYZ image which preserves the same appearance but is viewed under the printing viewing conditions using the reverse Hunt '93 model. Finally, the XYZ image was processed to achieve CMY or CMYK images using the printer models [LUO92].

It is clear from the preceding debate that the three stage CIE transform upon which so many colour matching applications are based is insufficient at providing the required degree of colour matching accuracy. The conditions necessary for the three stage transform to be truly effective are virtually impossible to attain given the diverse nature of prepress production. The recommendation of the Seybold panel *that future prepress systems should work with device independent colour*[SEY92c] is only realistic providing the current three stage transform is extended to include the principles of Hunt's colour appearance model. Both MacDonald and Luo advocate the use of Hunt's forward/reverse models to transform XYZ to perceptual LCH to XYZ. The purpose being to address the inconsistencies that occur with the three stage transform in relation to changing viewing conditions. However, caution needs to be exercised regarding the number or transforms involved in a colour matching application that allows for changing viewing conditions. The rationale behind this suggestion is that multiple transforms/conversions often require time consuming calculations which inevitably involve some form of round-off error. A direct consequence of this is that there is a loss of colour information and a reduction in the level of quality delivered.

6.2. Appraisal of Screening Technology.

6.2.1 Rational Supercell Technology

It has been shown that one of the major difficulties associated with the implementation of colour applications on the desktop has been the hideous moiré patterns that occur as a consequence of inaccurate screening during the colour separation process. However, a number of applications based upon rational supercell technology have attempted to eliminate this problem. Therefore, it is believed that it is essential to asses their validity by means of a critical examination of current debates that surround this issue.

As part of their San Francisco conference held in September of 1992, the Seybold organisation carried out a *Color Screening Shootout* exposition in which 22 printed samples produced using 22 devices from 16 different suppliers were evaluated on issues relating to colour quality. The primary objective of the exposition was to evaluate the performance of various screening technologies as opposed to determining "winners" and "losers" amongst suppliers. The printed samples were assessed by a panel of seven judges, all of whom were selected from within the prepress community. An appraisal of the panel's collective verdicts on the printed samples produced using the rational supercell screening technique form the basis of the current critical examination of this emerging screening mechanism.

The judges were required to asses printed samples on the issues of screening quality listed below:

- *Dot Shape- occurrence of screening defects caused by variation in shape as dots increase in size across the tonal range;*
- *Dot Edge- defects such as sudden drops resulting in noticeable edges or lines, a grainy appearance, or increased dot gain;*
- *Area smoothness- in large areas of the same colour,*

without graininess or colour shifts.

- *Rosette patterns, dot structure-noticeable patterns that might be obtrusive, and inconsistencies in dot or clear clustered structures across an area;*
- *Moiré- occurrence of distracting patterns;*
- *Banding- lines or breaks that interfere with the smooth gradations in vignettes;*
- *Overall page appearance- any factors that might cause a buyer to reject the page. This was the most subjective category* [SEY92b].

The test samples printed were produced at three different frequencies i.e. 133lpi, 150lpi, and 175 lpi. These frequencies were selected as they are representative of those commonly used within a commercial environment. The images that were screened were deemed to be very demanding with the intention being to expose screening inadequacies as opposed to highlighting the strengths of a particular screening mechanism.

The conclusions of the panel of judges were that the *best quality results for PostScript colour were probably turned in by vendors of traditional imagesetters i.e., the big three typesetting suppliers Agfa (formerly Compugraphic), Linotype-Hell (formerly Mergentahler Linotype) and Tegra / Varityper (formerly Varityper* [SEY92b]. It is interesting to note that each of the above vendors have devised their own screening mechanism (with Linotype using its High Quality Screening (HQS), Agfa using Agfa Balanced Screens (ABS), and Tegra using ESCOR). However, one sample that was printed using Adobe's Accurate Screens delivered acceptable colour results. Overall screening techniques based upon the rational supercell mechanism performed relatively well, but no sample was considered to be "perfect".

In retrospect it is important to consider that one of the judges on the Seybold panel commenting on the state of the art in PostScript colour screening pointed out "there has been a lot of progress in the past few years". However, he quickly added, "we haven't arrived yet. One thing these tests have demonstrated", he continued, "is that across the board consistency is still lacking with most of these machines. They may be able to produce output that is attractive to the eye on any particular job, but if the rosettes or dot shapes are inconsistent across the page, if output at some frequencies looks good and some doesn't, or if registration isn't always right on how much can you count on these devices when production flow is on the line and your business is at stake? In most real world situations you don't have from 9 a.m. until 11 p.m. to get the job out with multiple tries to get it right". [SEY92b].

A number of criticisms can be levelled at the Seybold *Colour Screening Shootout* exposition. The major weakness of the Seybold exposition is that the judges were required to evaluate the printed samples using their own words. This resulted in large inconsistencies between judges opinions. For example one printed sample produced at 175 lpi using a device from the Margent Group received one excellent rating, whilst the rest of the panel judged the sample between OK and unacceptable. It is believed that a numerical type weighting system should have been employed in order to deliver accurate quantitative data (such as the LUTHCI Colour Appearance Data [LUO92]) as opposed to qualitative type responses. However, it is important to note that a qualitative evaluation of screening technologies was the primary aim of the Seybold exposition. Another criticism is that the suppliers of the devices used to render colour separations set up their own devices and used their own staff to produce the colour separations. Also the system suppliers were given extended time allowances in which to produce the separations, this essentially allowed suppliers to "tweak" their devices so that they performed to their maximum capability.

Considering the above it is believed that the Seybold Colour Screening Shootout would have been far more worthwhile if the judges had been required to asses the printed samples using a ranking system which would have delivered accurate quantitative data, as opposed to ambiguous qualitative data. Additionally, the tests themselves should have been carried out by potential and existing users (e.g. repro houses, trade service bureaus etc..) using their experienced personnel. Also it is believed that the tests should have been carried out within specified time limits that reflected the typical time allocated to performing these tasks in industry. Not only would the test prints have been far more realistic in that they would have been produced in conditions that are representative of conventional prepress, but also other features of screening technologies could have been evaluated such as ease of operation, speed, and productivity etc.. However, the argument put forward by Seybold *that it would have been nearly impossible for users to set up and implement a comprehensive test* [SEY92b] is noted.

Users opinions on the printed samples produced using rational supercell techniques indicated *that many of the samples would be acceptable, but there was no agreement on which ones were good and which ones weren't* [SEY92b]. Other users have also expressed their opinions on the ability of PostScript Screening. Michael Sullivan of INS Info Services (USA) replying to a question posted on the comp.publish prepress bulletin board (01/05/94) which asked *Is electronic screening still in its infancy?* commented "that the answer is probably yes. For low - medium work it is acceptable and has been for a few years. Only recently have PostScript imagesetters started using techniques which can be considered acceptable for high-level work". John Doherty of G&S Typesetters (USA) responding to the comments of Michael Sullivan on the comp.publish.prepress bulletin board (01/05/94) commented that "the latest and greatest PS screening technique is frequency modulated, which I have not had the opportunity to work with. Some of the printed pieces I have seen that use it produced excellent results easily equal to those achieved by traditional color electronic prepress systems (e.g., Scitex, Crosfield, et al)". Murray Stroud of the Adplates Group related a very different experience of using PostScript Screening outlining that *PostScript had introduced extra processes, increased costs, slowed down production, lost markets, lowered quality, forced lower prices and reduced process control* [SEY94].

The above inconsistencies in users opinions reinforces the notion that judging colour quality will always be subjective and open to an individual's interpretation of what constitutes an acceptable level of colour quality.

6.2.2. Appraisal of FM Screening

The introduction of frequency modulated (FM) screening has aroused significant debate within the graphic arts community regarding its viability as an alternative screening mechanism.

Prepress vendors that have applied FM technology within their product range envisaged that their customers would experience substantial benefits in relation to quality and imaging speeds. The nature of these benefits include:-

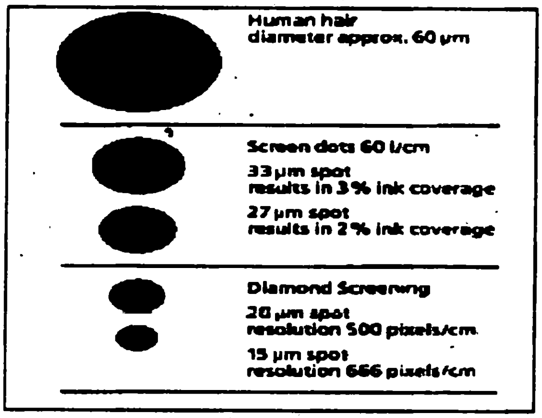
- *no moiré from patterns in the original;*
- *no rosettes, which are especially noticeable when printing with line screens under 60 l/cm;*
- *no dependency between resolution, screen frequency and number of gray levels;*
- *low imagesetter resolutions with no loss of quality, thereby faster computing and imaging speeds;*
- *enhanced quality for newspapers and electronic publishing systems which typically work with lower screen rulings;*
- *higher level of ink feed, therefore greater brilliance in print;*
- *smooth gradations with nom banding;*
- *greater definition of very fine detail;*
- *moiré-free printing of more than four colours;*
- *enhanced ink/water balance during printing, lower start-up waste.* [FRI94]

However, Friemel maintains that *many printing experts still have a negative image of frequency modulated screening, associating it with laborious assembly and copying processes, excessive plate wastage, excessive press downtimes and, last but not least, unreliable production* [FRI94].

In considering the above it is apparent that there is a large degree of inconsistency between the potential benefits envisaged by prepress vendors and the negative experiences related by printers. However, Friemel suggests that there are a number of factors responsible for stimulating these inconsistencies. The quality and consistency of FM screening, like any other screening technology, is determined by the precision and reliability of the apparatus that it is incorporated within.

One of the key factors responsible for promoting inconsistencies arises from problems encountered during the platemaking stage. Often printers experience difficulties in achieving a successful transfer of 2% (27µm) and 3% (30µm) dots of a conventional 60l/cm screen to the printing plate. However, it is important to consider that FM dots are significantly smaller than those used in conventional screening with diameters of 20µm and 15µm (see figure 6.3). Therefore, the problem of achieving the correct transfer of FM dots to the printing plate is exacerbated by their minute size.

Fig. 6.3. Comparison of Halftone Screen Dots/FM Dots Diameters with a Human Hair



Source: Friemel, E., FM Screening: Reliabilty in Production, Deutscher Drucker, Issue 46, Dec.'94.

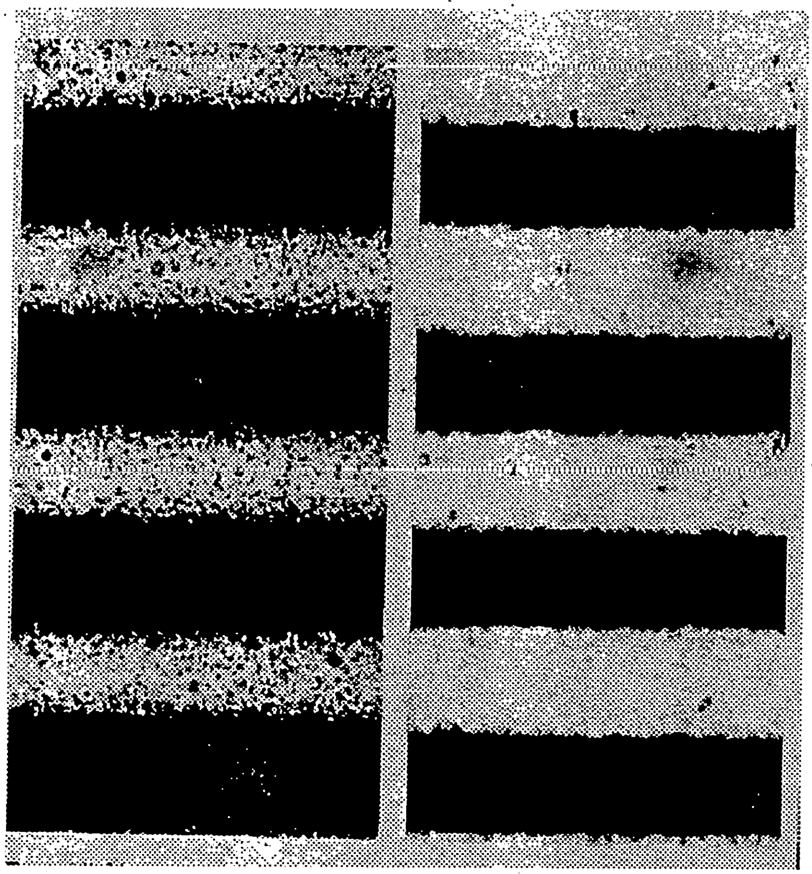
Unlike conventional screening where quality is dependent upon the screen frequency selected, FM screening quality is governed by the dot diameter. For example a 15µm dot is an appropriate choice for work demanding absolute quality. 20µm dots are considered appropriate for all standard applications, whereas 30um dots are often used in newspaper reproduction work [FRI94].

FM dots that are above 30µm lie in the dot diameter range of conventional 60l/cm screens. Consequently, no problems should be encountered in the copying stage. With 15um and 20um dots, quality factors are compounded by a compromise between the recorder speed and the reliability of the copying process.

However, Friemel maintains that achieving the correct transfer of 20µm and 15µm dots from film to plate can be substantially influenced by: the choice of film, film technology, and printing procedures.

The selection of film to be used in conjunction with FM screening can influence how well the image will be transferred to the printing plate. Resolving power and image focus have always been key quality criteria for films. Films that transfer successfully to the printing plate are often characterised by their *steep gradation*. Lith films usually posses good edge steepness, however variations encountered during their development (e.g. temperature, development time, chemical balance) result in inconsistent quality. Line films traditionally used in conventional screening are not as susceptible to variations in development but suffer from a lack of edge steepness compared to lith films. With the continuing evolution of halftone film, improvements are being made all the time and this is indeed essential to ensure reliable copying and production in conjunction with FM screens. Such improvements have manifested themselves in new hard dot films. The difference between the quality of a conventional line film and a hard dot film is clearly demonstrated in figure 6.4.overleaf.

Fig. 6.4. <u>500x Magnifacation of 20um Lines/20um Spacings (50% Coverage) Imaged on a SLD Film and Kodak 2000 Series Film.</u>

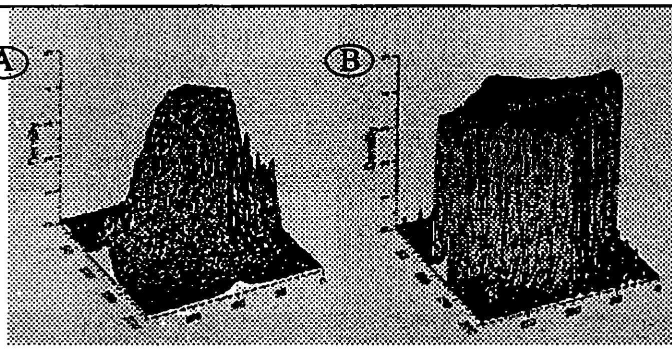


A linotronic 330 was used to image a number of horizontal lines of thickness 20µm at intervals of 40µm in order to produce a grid structure of 20µm lines and 20µm spacings. This corresponds to the screen frequency 500l/cm with a coverage of 50%. The grid was imaged onto a standard *Imagelite LDF* line film and a *Kodak 2000 series film* of type *SLD*

Source: Friemel, E., FM Screening: Reliabilty in Production, Deutscher Drucker, Issue 46, Dec.'94.

The difference in quality is readily apparent. The coverage in the SLD film is 51% and is virtually identical with the input. Consequently no imagesetter linearization is required. The coverage with the line film is 74%, however. Expressing these figures in gradient terms, gives figures of 6-8 for the line film with 16-18 for the 2000 series film [FRI94]. The superior quality of hard dot films is a direct consequence of the ultra steep square dots of uniform diameter they generate. Figure 6.5. shown below is a magnification of a microdensitometric recording of dots produced on a conventional film and a hard dot respectively.

Fig. 6.5. Microdensitometric Recording of Dots Produced on a Conventional Film and a *2000* Film



Dot A- Magnification of the microdensitometric scan of a line screen dot. While the dot structure is steep, it is still pyramidal. The tip in no way corresponds to the required dot diameter which also differs from one intensity level to the next.

Dot B- The *Integrated Booster Technology* of the *2000 series* films generates ultra-steep perfectly square dot shapes of uniform diameter, and does so for even for different densities. The booster secret: Image elements in the area of the dot which have been imaged only slightly are included in the development process and are blackened fully.

Source: Friemel, E., FM Screening: Reliabilty in Production, Deutscher Drucker, Issue 46, Dec.'94.

The dot on the conventional line film (A) exhibits a steep pyramidal hill type structure while the hard film (B) is characterised by vertical edges. This comparison demonstrates why the process of copying films onto the printing plate is more reliable.

The variations in the profiles of dots shown in figure 6.6. are a consequence of *Integrated Booster Technology* developed by Kodak and applied in their *2000 series* film. The density profile of dot B *assumes a rectangular form due to the fact that unexposed image elements of the dot are also incorporated into the development process. This produces the required rectangular shape. This process is supported by an inhibitor which ensures that transitions from blackened to transparent areas have no unsharp edges. The coordination between booster and inhibitor produces a binary effect - either optimum blackening with logarithmic densities over 5.0 or transparency with an extremely slight background fog. This is what sets Kodak's development product apart from other hard dot products* [FRI94]

Probably the most important factor governing the accuracy and success of the 2000 series film is that the *Booster* and *Inhibitor are embedded in the film layer and are activated during the development process. This has the advantage of high stability and minimum deviations in the event of fluctuations in the replinisher. There is often no need to perform basic calibration of the imagesetters since output and input match for a given ink coverage* [FRI94].

The *Kodak 2000* approach of having important development components embedded in the film is supportive of an open system because other films can also be developed using the hard dot chemicals. However, using other films that are more susceptible to variations encountered during recording and development requires increased operator intervention (e.g. frequent calibration of imagesetter and minimising deviations in the development process)

As indicated earlier it is in the platemaking stage that many printers experience difficulties in achieving a successful transfer of FM dots to the printing plate. Therefore, it is necessary to establish the extent to which improvements in film technology have addressed the problem of inaccurate transfer.

One of the major problems associated with the transfer of FM dots to plate is that many manufacturers of FM screens recommend exposing high resolution plates (4-6um) at low K values (K6, K6-8). The K value, specified by FOGRA, determines the number of light cycles the plate is exposed to, see figure 6.6. below:-

Fig. 6.6 FOGRA K Values

K4 - 6 = 8 cycles.
K4 - 8 = 10 cycles.
K8 - 10 = 12 cycles.
K 10 - 12 = 15 cycles.

Source: Friemel, E., FM Screening: Reliabilty in Production, Deutscher Drucker, Issue 46, Dec.'94.

Exposing high resolution plates at low K values can have significant disadvantages, namely:-

- *the requirement that no dust be present during the mounting and copying stages is unrealistic. Since printing shops are not hospital operating rooms, the high costs associated with defective copies and press downtimes are always on the agenda;*

- *reduced light cycles result in the unprotected plate coating insufficiently broken down in the case of the positive copy, or being insufficiently hardened for the negative copy. As a result, printing plates exhibit scumming during the print run;*

- *copying recommendations at low K values relate to FM screens which are imaged onto standard line films and generate an edge zone area of varying size. Each fluctuation in the imaging and development processes has an over-proportional effect, prevents standardization and can also cause defective copies and printingpress downtimes* [FRI94].

However, Linotype-Hell recommend copying at k 8 - 10 if *Kodak 2000 series* films are used in conjunction with their *Diamond Screening*. This is only a slight deviation from the standard K values used in conventional screening (see figure 6.7)

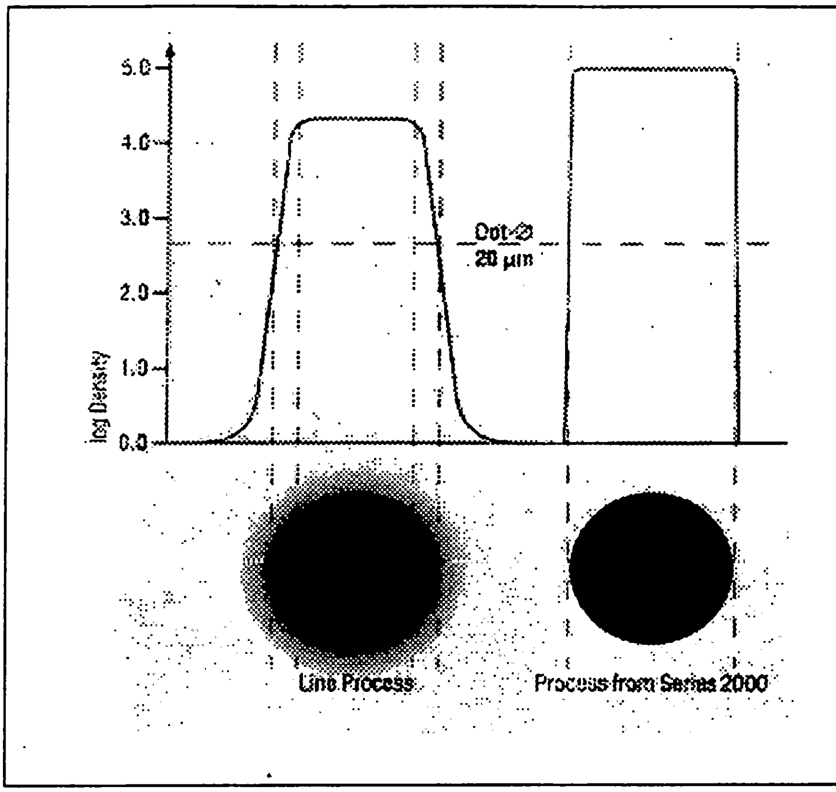
Fig 6.7 Standard K values used in conventional screening

Plate Resolution 4 - 6µm = copying at K value 10 - 12
Plate Resolution 6 - 8µm = copying at K value 12 - 15
Plate Resolution 8 - 12µm = copying at K value 15 - 20

Source: Friemel, E., FM Screening: Reliabilty in Production, Deutscher Drucker, Issue 46, Dec.'94.

The relationship between improvements in film technology and the successful transfer of FM dots during platemaking is clearly illustrated in figure 6.8.overleaf.

Fig. 6.8 Copying Behavior of Line Films and Hard Dot Films of the *2000 Series*



Source: Friemel, E., FM Screening: Reliabilty in Production, Deutscher Drucker, Issue 46, Dec.'94.

By examining the above figure it is readily apparent that the core blackening of the line process dot lies well below the required 20um. Copying is performed within a grey range. Fluctuations in plate exposure alters the range generating dots of varying diameters. Such variations *cannot be accommodated by the colour zone controls of the printing presses and call for a new copy to be performed with modified light cycles, and of those there is little need to talk about the costs involved, particularly those brought about by press downtimes* [FRI94].

However, with the 2000 series process, the dot diameter corresponds to the required 20um value, which is retained even when the density fluctuates. This ensures the required reliability in production.

Agfa and Crosfield also advocate the use of hard dot films in order to ensure that films transfer to plate successfully (see 5.2.2.).

Having overcome many of the difficulties experienced in the platemaking stage, FM screening applications continue to suffer from a number of problems:-

- With conventional halftone screening, the resolution of text and vector feature edges at tint colours of 100% are defined by the raster resolution of the output device. With FM screening the raster resolution of the output device is equal to the size of the FM screen dot which is typically four times larger than the raster resolution of the output device used for halftone screening. This can cause jagged edges on text and vector features that have tint colours of 100% density. In order to avoid this effect many users opt to produce an additional black film in which the imagesetter resolution is increased. However, such a technique increases the time and cost involved in the production process, especially if one considers that an extra black plate is required. Another possibility involves processing each separation at a higher resolution (1600 -1800 dpi) thereby eliminating the need to generate a fifth black plate. The former solution would prove prohibitive for a publication containing multiple type intensive sections as a fifth black plate would have to be generated for each section. Also such a solution would prove unattractive for printers running four station presses as a second run would be required exacerbating registration problems etc. The latter solution is more appropriate, however, it compromises the advantages that lower resolutions offer in terms of processing speed. As a consequence of this many users may decide to implement a conventional screening mechanism instead. Indeed, all vendors offering FM applications maintain that they are intended to complement rather than replace their existing screening mechanisms.

- The file sizes of images and pages when RIPed for FM screening can be 30% larger compared to the same size images and pages RIPed for halftone screening.

- RIP expose times are longer.

On the issue of FM screening it is clear that advances in film technology and platemaking have addressed the major concerns amongst printers regarding the ability of FM generated films to transfer to plate consistently. However, these advances are compounded by the tendency of FM applications to produce type that suffers from jagged edges. Therefore a users decision to implement FM screening will become increasingly dependent on the nature of type contained within a given job.

6.3. Appraisal of Additional Periphery Solutions

Adobe PixelBurst Chip - The introduction of the PixelBurst chip was seen as "a watershed event" by Seybold in that the arrival of the PixelBurst chip stimulated a major change in the potential market for high-resolution imagesetters. Previously the market had been dominated by those manufacturers whose embedded RIPs could process the bitmaps in the fastest possible time. Such manufacturers included Hyphen, with their hardware RIPs, Linotype with its TurboPix accelerator, and other manufacturers using Adobe's Emerald RIP. However, the arrival of the Pixel Burst chip means that any Adobe licensee can purchase a plug-in card from RasterOps that is able to process and deliver bitmaps at full print engine speeds. A consequence of this is that imagesetter design will have to integrate software from off - the - shelf workstations, network cards, marking engines and so on, all of which are available in open and competitive markets. Therefore, the advantages will shift to vendors who can engineer components to particular market niches. Both Adobe and its Emerald licensees have experienced delays in developing and applying high-end Level 2 products for the market. However, the existence of a ready-made accelerator makes software RIPs (such as CPSI) hosted on general purpose workstations, the logical way to proceed, and will actively encourage the adoption of new PostScript interpreters as they become available [SEY92a].

Therefore, it is believed that the implication of PixelBurst extends beyond its ability to accelerate PostScript for high resolution imaging devices. It also redresses the imbalance that exists between proprietary hardware controlled RIPs which dominate the market and software RIPs operating on standard platforms which will enable greater accessibility.

Aldus Trapwise- The introduction of Aldus Trapwise to the Aldus range of prepress applications should be viewed in the wider context as its introduction has resulted in almost the complete automation of the prepress process. Aldus already has PageMaker for page composition, PhotoStyler for image retouching, PrePrint for colour separation, and PressWise for imposition. Therefore Aldus envisage users running the above applications in tandem as a total prepress system. It is contended that there is already evidence to support this in that Aldus has integrated its existing applications so that they can be launched from within one another [SEY93]. Seybold also believe that in future that some Aldus applications will be absorbed into others and no longer sold as separate modules (PrePrint is likely to become part of TrapWise).

In terms of user opinions, Todd Morton of Impression Northwest (USA) indicated that "TrapWise has speeded up our work immensely. It has changed trapping from a laborious mechanical process into one where I can still apply my stripping knowledge but make the computer do all the tedious work. Its an incredible time saver" [ALD93].

JPEG File Compression - The performance of the JPEG compression mechanism remains a matter of contention amongst prepress users. John De Armond of Dixie Communications (USA) replying to a posting on the comp.publish.prepress bulletin board (09/06/1994) believes that "JPEG is the best image compression technology available today". However Bill Carbonelli of The Dorsai Embassy (USA) relates a very different experience of JPEG in his posting on the comp.publish.prepress bulletin board (09/06/1994) in which he outlines that "JPEG images, while perfectly viewable on a monitor many times do not translate well to printed media!" . Sterling Ledet of Sterling Ledet & Associates also related an unfavourable experience of using the JPEG compression mechanism in his posting on the comp.publish.prepress bulletin board (08/06/1994) in which he stated that "most procolor users notice a difference if comparing side to side and would elect not to use JPEG if given the option. Certainly JPEG is appropriate for high volume, low quality work, and it's great for image transfers over slow links. A panacea for image management? Hardly". The opinion of Ledet is supported by Anson's notion that *The JPEG assumption that higher frequencies are unimportant does not hold if the image has sharp edges Extending the higher frequency DCT-basis functions results in effects such as unwanted ripples spreading from the edges, called* ***Gibbs phenomenon.*** [ANS93]. Therefore, it would appear that it is appropriate to assume given the information above that the JPEG compression mechanism should only be used for low - medium colour work.

It is evident from the information outlined earlier that the successful implementation of emerging colour solutions is dependent upon an individuals interpretation of what constitutes an acceptable level of colour quality. In relation to colour matching schemes it is apparent that system designers and prepress journalists are confident that systems based on device independent colour are capable of providing accurate colour matches. However, the three stage transform incorporated into many colour management applications has been shown to be insufficient at accomodating changing viewing conditions. Therefore future applications should extend the current three stage transform to include colour appearance models based on Hunt's principles.

As regards emerging screening mechanisms there appears to be a general consensus that existing rational supercell screening applications are acceptable for low-to-medium colour work. However, there are inconsistencies regarding its application in high-end work. On the issue of FM screening it is clear that advances in film technology and platemaking have addressed the major concerns amongst printers regarding the ability of FM generated films to transfer to plate consistently. However, these advances are compounded by the tendency of FM applications to produce type that suffers from jagged edges. Therefore a user's decision to implement FM screening will become increasingly dependent on the nature of type contained within a given job.

7.0 Questionnaire Design, Production, and Analysis.

As part of this research a questionnaire was designed to survey the opinions of system users on the effectiveness of their individual systems at processing and delivering professional colour. The intended purpose of the questionnaire was to allow a comparison of the information derived from replies with information from the "current debate" findings. The manner in which the questionnaire was conceived, designed, and produced is the focus of attention here.

7.1 Questionnaire Conception

During the preliminary stages of the research programme into colour prepress systems it became clear that there were a number of debates that challenged the validity of emerging colour prepress applications and their underlying technology. It was realised, therefore, that there was a need to asses the findings of these debates by comparing them with other sources. However, the problem remained of establishing other sources and how these would be sampled. The vast majority of current debates were based upon the findings of specific research projects whose primary aim appeared to be enhancing a particular facet of prepress technology or evaluating the performance of selected colour spaces in relation to their colour matching ability through a process of visual experimentation.

Attempting to embark upon a research programme that was similar in nature to those outlined above would have involved the employment of significant resources that were unavailable at the time of this research programme. Also such programmes require extensive scientific and technical knowledge to be truly beneficial. Another factor that precluded the pursuit of an extensive research programme was that the time constraints imposed by the degree program itself had to be taken into account. In considering the above factors it was determined that an appropriate methodology would be to seek the opinions of users on the effectiveness of their systems at processing and delivering acceptable colour. This was to be achieved using a questionnaire which was to be completed by appropriately selected respondents. The rationale behind seeking users opinions is that was believed that system users would provide a valid evaluation of colour solutions as they are using them in the commercial environment for which they were designed.

7.2 Questionnaire Design

A comprehensive understanding of questionnaire design concepts is necessary in order to ensure the delivery of valid and accurate statistical data from the survey. In designing the questionnaire the first objective was to determine its fundamental intention (e.g. to verify a hypothesis, accumulation of statistical data etc.); This was, by comparison, to establish the validity of current debate findings. In order to achieve this objective the questionnaire had to incorporate a number of key concepts including those given below.

a) Request for Co-operation - In the introductory stage of the questionnaire respondents were informed of the intention of the survey, along with a request for their co-operation.

b) Instructions for Respondents - Also in the introductory stage of the questionnaire instructions were given on how the questionnaire should be completed. This section of the questionnaire was entitled "Completing Your Questionnaire". Here instructions relating to the proper use of ranking schemes and multiple choice questions were provided.

c) Information Sought - This section of the questionnaire was essentially subdivided into three separate sections including: -

About Your Company - This sub-section primarily involved respondents identifying themselves, i.e. details relating to the name and address of their organisation etc. However, respondents were required to give details of their turnover, staff numbers, and allocation of work (e.g. black and white work, spot colour work, and full colour work). The rationale behind these questions was to establish whether there was a relationship between the size of an organisation and the equipment it possessed. In establishing the existence of such a relationship a number of rudimentary assumptions could be made. For example it is highly probable that larger organisations posses larger purchasing budgets and could therefore be more selective in their purchasing decisions. Therefore if larger organisations who have the ability to purchase high-end proprietary equipment were instead opting to buy lower end PostScript colour solutions it would support the notion that PostScript based applications are capable of delivering a professional level of colour. Also larger organisations are more inclined to be involved in the preparation of more complicated colour work. A consequence of complex colour work is that it makes increased demands on the system being used. Therefore, if larger organisations are prepared to use PostScript applications to process complex colour work as opposed to using more traditional equipment, this again reinforces the assumption that PostScript is a viable alternative for processing professional colour.

About Your System - The purpose of this sub-section of the questionnaire was for respondents to identify their system configurations. In establishing the nature of user system configurations it could be demonstrated whether PostScript colour applications were being widely implemented within the prepress industry. Also for those respondents who identified themselves as being users of PostScript colour applications the attention was to pay particular attention to their opinions on the level of colour quality rendered by their system. Accumulating these opinions would enable comparisons to be made with the findings of current debates regarding aspects of colour quality. Another important feature of this section of the questionnaire was that it sought to establish whether users were calibrating the devices within their system, and if so, what was the typical frequency of their calibration. Therefore, we anticipated establishing the existence of a relationship between device calibration and the quality of the colour delivered. For example we anticipated that users who calibrated their devices on a regular basis were more likely to be content with the quality of colour rendered by their devices and vice versa.

Your Opinion on Your Colour Prepress System - This was to be the most important section of the questionnaire in that users were given the opportunity to appraise the performance of their colour prepress system. The majority of questions within this section required users to rank the performance of their system on a number of specific issues related to colour quality. The manner in which respondents were to rank their system involved them using the numeric weighting scale provided. It was believed that using a numeric weighting scale would ensure the delivery of accurate quantitative data as opposed to ambiguous qualitative data. The aspects of colour quality which warranted user evaluation were halftone screening and colour matching capability. The reason for this approach was that both of the above aspects of colour prepress have attracted considerable research and attention in recent years, and as a result various applications derived from such research have been introduced in the prepress marketplace. Emerging colour applications and their underlying technology often attract critical analysis from eminent writers within the prepress community. Therefore it was decided to appraise their findings by comparing and contrasting them with users evaluations. Users were also invited to make additional comments on the effectiveness of their colour publishing system. The purpose of this was that it gave users the opportunity to highlight any issues relating to colour quality that had not already been covered in our questionnaire.

In order to supplement the findings of the postal questionnaire additional research was undertaken. Such research involved interviewing local prepress organisations on colour quality related issues. The responses given by users were recorded on audio tape and later transcribed on a modified questionnaire. The modified questionnaire still contained many of the questions present within the original postal questionnaire, however, it had within it some additional open ended questions. The purpose of such questions was to identify how users envisage the current situation of colour prepress in terms of trends, concerns, and expectations.

7.3 Questionnaire Production and Distribution.

7.3.1 Questionnaire Production

Production of both questionnaires involved preliminary drafts being designed and constructed in manuscript form. These were then transformed into a final printed document using PageMaker version 4.0. The postal questionnaire and modified questionnaire are included in the appendix as figure B1 and B2 respectively.

7.3.2 Questionnaire Distribution -

In order to ensure that the survey was accurate and valid it was necessary to establish an appropriate sample group that was an accurate representation of the colour prepress industry. The method by which the sample group was compiled involved identifying colour prepress organisations through the Benn Printing Trades Directory 1993. One particular section of the directory itemised those organisations engaged in performing colour prepress work. For each organisation that was listed details relating to their services and equipment were provided. Given this information it was possible to establish a diverse sample group that was representative of the entire colour prepress industry. The sample group involved sixty five respondents receiving their questionnaire through the post. The number of respondents chosen to participate within the survey was based upon the notion of A.N. Oppenheim who suggests that postal surveys generally experience a response rate of 40 per cent [OPP92]. If this were the case then one would expect that approximately 25 questionnaires would be completed and returned, which was believed to be sufficiently large enough to derive quantitative data from. The rationale behind the selection of a mail survey was that it enabled respondents who were located at widely dispersed addresses across the United Kingdom to be reached. Users that participated in the *one to one* interviews were located within the Cardiff area. Selecting appropriate respondents involved telephone conversations with potential users in which the nature of their prepress activities were established. If users conformed to the required criteria then an appointment was arranged. Users that agreed to participate in such interviews are listed below:-

Cardiff Typesetting Company, 45 Llandaff Road, Cardiff.
(Contact- Tom, 01222 239185)

Just Reprographics, 76a Upper Kincraig St., Roath, Cardiff.
(Contact- Mike , 01222 452633)

MicroStar/Ferguson Cowie, 31 Ardwin Rd, Pantmawr, C'diff.
(Contact- Mike Cowie, 01222 529800)

P.I.A. Ltd, 37 Charles St., Cardiff.
(Contact- Mike Southern, 01222 222782)

Qualitex, Tudor Road, Cardiff.
(Contact-Dennis,01222 228008)

Quantum Reprographics, 139 Maindy Road, Maindy, Cardiff.
(Contact-Joe, 01222 640222)

Scanagraphics ltd,101 Portmanmoor Road, Cardiff.
(Con.- Andrew, 01222 493711)

Uppercase, 21 West Bute Street, Cardiff Bay, Cardiff.
(Con. - Russell, 01222 490084)

7.4 Response to Questionnaire

As outlined earlier it was anticipated that approximately twenty five completed questionnaires from the sample group would be received. Eventually, twenty seven completed postal questionnaires (approximately 40% of our sample group) were returned. This was in accordance with the original estimate. Also given the eight questionnaires completed in the *one to one* interviews the total nuber of respondents totalled thirty five. This, it was believed was an adequate number of responses from which to derive quantitative data. For those organisations which failed to respond to the original request for co-operation it was decided that an informal reminder letter should be sent to them. However, this proved to be a futile exercise in that it failed to yield any increase in responses returned.

7.5 Results of the Questionnaire Survey

The results of the questionnaire survey are essentially a dichotomy between the quantitative data from all completed questionnaires and the qualitative data obtained during the *one to one* interviews. The quantitative data is represented as a series of tables and graphs in the pages that follow. The data is analyzed in the proceeding section (see 7.6.) in which the qualitative data of the *one to one* interviews is also incorporated.

Questionnaire Results

Fig. 7.1. Distribution of Prepress Activity

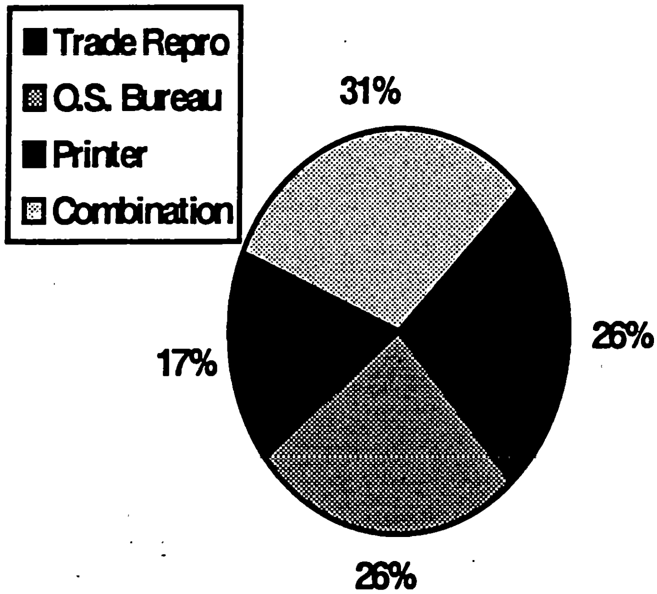


Fig. 7.2. Colour Work Undertaken By Survey Respondents

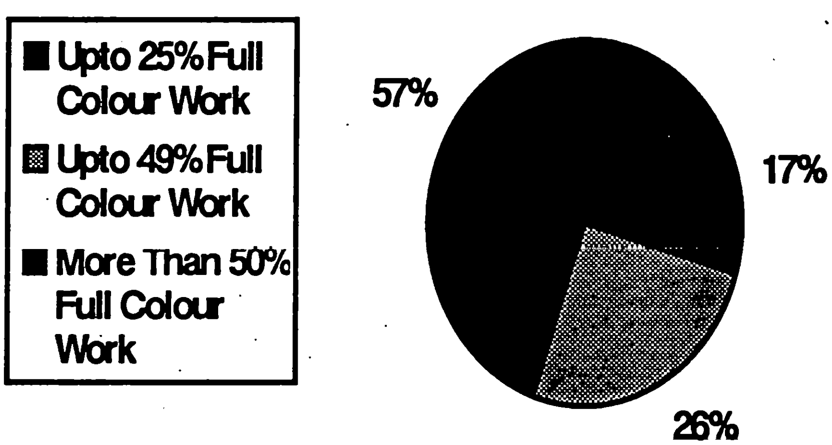
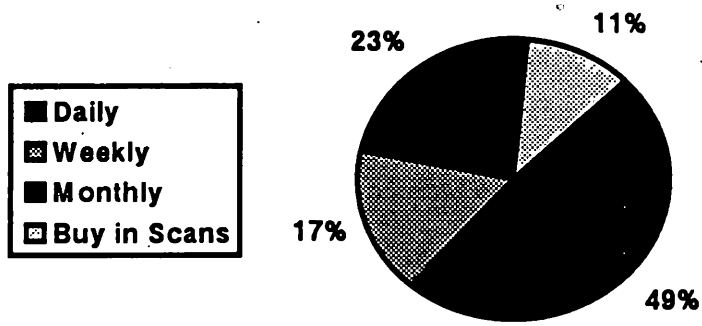
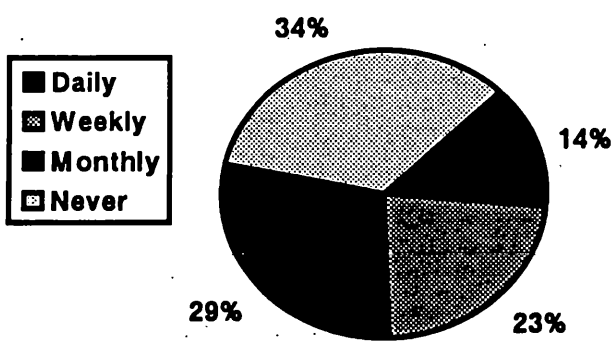


Fig. 7.3. Device Calibration Practices of Survey Respondents

A.Input Device Calibration



B. Display Calibration.



C. Output Device Calibration

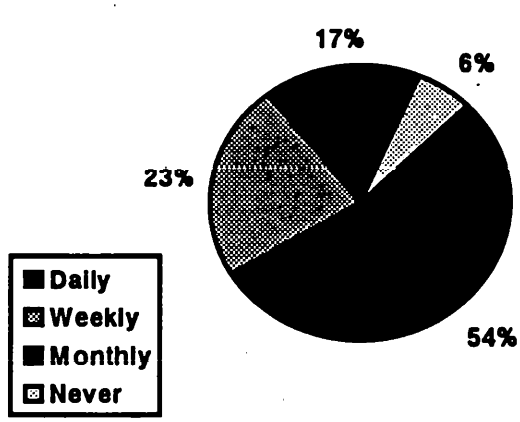


Figure 7.4.

Results of Questionnaire Survey

	Beyond Your Expectations	Fully Meets Your Expectations	Adequately satisfies your basic expectations	Fails to meet the majority of your expectations	Totally fails your expectations
At What level does your system meet your expectations?	14%	37%	49%		

Rankings Assigned By Users On issues of Quality (Expressed as a Percentage)

	Failed to Answer	1	2	3	4	5	6
Producing consistent halftone dot shape/edge.					9	31	60
Producing Consistent Rosette Patterms	6				20	11	63
Delivering moire free colour separations.				6	14	11	69
Ensuring accurate trapping.				3	20	40	37
Ensuring Accurate Imposition	9				23	34	34
Delivering/handling vignettes.	3	6	6		11	37	37
Maintaing Colour Fidelity between the original and the reproduction				6	31	26	37
File compression/decompression performance (in relation to image quality)	20				23	31	26
Reproduction of metallics, fabrics, and fleshtones.				14	26	29	31
Performance of network/servers.	9			20	37	23	11
Speed in processing colour images/ colour separated halftone film.		6	14	9	9	31	31

7.6 Analysis of Returned Questionnaires

As indicated earlier in the abstract of this investigation, one key objective of the research is to validate current debate findings by comparing them with statistics derived from the questionnaire survey. It would be very difficult to achieve the above by only referring to the statistics provided in the *results* section. Therefore the statistics/results require a degree of interpretation if a valid comparison is to be made.

Probably one of the most interesting features of the information presented within the results section is the graphic relating to the nature of prepress activity. From initial inspection it appears that there is a relatively even distribution amongst users regarding the nature of their prepress activity. However, on closer inspection, those users who specified that they were involved in more than one if the activities listed revealed an interesting and significant trend. All such users considered themselves to be a combination if a traditional reprographics studio and an output service bureau. This in itself is significant because it represents how the nature of prepress has changed over recent years. Probably the most significant change has been the increasing popularity of ouput service bureaus over traditional reprographic studios. This has been brought about by designers and agencies becoming much more involved in the production process through the use of relatively inexpensive DTP technology. The degree of involvement that a designer/agency typically has in the production process extends to the completion of the PostScript file that requires processing into separated films. Therefore, the designer/agency only has need of the service bureau at the film separation stage. As a consequence of this many of the expensive and time consuming services previously offered by a traditional reprographics studio (e.g. planning and stripping) are now obsolete, and can be performed much more effectively using comparable software applications. Many reprographic studios have recognised this and as a consequence have adapted to the situation by offering the same services as those provided by output service bureau (i.e. output of PostScript files on film). Many have achieved this by configuring their existing equipment within an *OPI* framework or through the acquisition of new equipment, namely imagesetters. Indeed, all those who considered themselves as being a union of studio and bureau had imagesetting facilities.

Examining users comments regarding issues of colour quality supports the existence of the changes described. Many users that participated in the *one to one* interviews specified that colour quality deteriorated substantially as a result of **customers increasing involvement in the production process**. Thus, reinforcing the notion that increased customer involvement is now standard practice within prepress. However, the experience of users suggest that changes in standard practices have not been without their consequences. Probably the most serious consequence has been the adverse effect on prepress colour quality as evidenced by the following extracts.

In reference to the issue of colour quality one user said "it's gone down I'll say that!, because of the level of our customers ability, what we're producing now is a lot worse than we were producing before Macintosh took over". Other users relayed similar experiences of lowering colour quality within the prepress industry. Indeed, one user commented, "we are having to cut corners, and our standard is not as high as we would like it to be. People want more colour but it is not as good as the colour quality you would have expected from repro, but customers are willing to accept it". Another user argued that "standards have dropped dramatically there's no doubt about that".

The above comments outlining the apparent deterioration of colour quality are representative of how the majority of those interviewed perceived the colour quality issue. The above comments also suggest that customers seem unconcerned about declining standards of colour. In relation to customer concerns regarding colour quality further investigation revealed that many users hold customers responsible for both lowering standards and for creating unnecessary production problems through errors on the files supplied. One user in particular articulated what many in the prepress industry see as the current situation. The user commented that "anyone can have a Mac, buy in low res. scans, do the work yourself, therefore you the customer dictate the level of colour quality produced. Whereas someone like us (a reprographics studio) will charge X amount of pounds per hour to do pixel editing etc.. If you as an agency don't have the money to invest in the type of equipment we have, then you are not going to waste your time as an agency worrying about aspects of quality you cannot control". The same user also emphasised that the majority of problems encountered during production were a consequence of errors on files supplied by customers. "Our main problem is that our customers don't understand trapping, and when trapping errors occurs they assume our registration is out, when in fact it is correct, it is their files that are at fault. Other users also suggest that many of the problems they had experienced were derived from errors on files they received from customers. As the following extract demonstrates "originally when we started with this system 18 months ago we thought that problems we were experiencing were our fault when in fact it was errors within customer files. We now run a series of checks to eliminate any potential problems that might arise".

In hindsight it is clear that many prepress users are of the opinion that colour quality has deteriorated since the introduction of desktop technology. However, the majority of those questioned argue that this trend of deterioration is a consequence of customer expectations coupled with customers increasing involvement in the colour reproduction process itself. The problems experienced by users in respect to errors on files supplied to them demonstrates ,to an extent, a lack of professionalism on the part of those customers producing their own colour work.

As indicated earlier by one user "people want more colour". Such demand has been brought about by cheaper production costs facilitated by the introduction of inexpensive prepress applications. Unfortunately the experience of users has shown customer ability to be lacking.

The graphic relating to users "allocation of prepress work" (see figure 7.2.) is very important as further investigation revealed that users opinions on the performance of their system on other colour quality related issues were severely influenced by their allocation of colour work.

In referring to the graphic alone it is clear that every user who completed the questionnaire had the ability, equipment, and applications to process full colour work. This in itself is significant as it demonstrates the continuing proliferation of vendors providing CMYK film separations.

On cross referencing those respondents who identified themselves as being output service bureaus with the sample group it emerged that the vast majority were listed as typesetters in the Printing Trades Directory. Like reprographic studios, typesetters have also had to modify their traditional services (i.e. producing type and spot colour on early generation imagesetters) in order to accommodate changing customer needs. The nature of modification pursued by typesetters over recent years has been to invest in technology that can process the colour files of customers. In order to process full colour work effectively a typesetter would require an internal drum type imagesetter that is compatible with PostScript level 2 and is driven by a high speed RIP incorporating a supercell screening technology. Such a device would ensure that the vast majority of colour separated film output was of an acceptable standard.

Although many more vendors now have the capacity to provide CMYK separations it is important to establish the proportion of work allocated by users to four colour processing. From examining such data in conjunction with the data concerning issues of quality, it emerged that a relationship existed between two sets of data.

Generally, users whose full colour work accounted for over 50% of their total business assigned rankings of 5 and 6 to the majority of quality issues related to system performance. Whereas users processing less than 50% full colour work typically assigned lower rankings of between 2 and 4.

Also the proportion of work allocated by users to full colour work influenced the frequency of device calibration implemented by them (see figure 7.3.). The vast majority of users who calibrated their devices on a daily/shift basis were those producing more than 50% full colour work. Indeed such users constituted 76% of those calibrating their input device on a daily/shift basis. The respective figure for output device calibration was 79%.

The relationships described above are to be expected if one considers a number of relevant factors. Firstly, users processing more than 50% colour work are far more inclined to possess superior equipment and personnel which reflect the higher rankings assigned by them. In relation to device calibration users processing high volumes of process colour work require system devices to be calibrated more frequently in order to ensure that acceptable levels of quality are maintained. However, users that predominantly concentrate on monochrome and spot colour jobs find that such work is less demanding in terms of what constitutes acceptable quality.

Up until now the analysis has been concerned with general changes that have occurred within the prepress industry. The purpose of the analysis that follows is to establish how users perceive the performance of their own systems. The analysis itself is based upon a combination of the quantitative data and qualitative data obtained in the *one to one* interviews. In conjunction, they reveal how effective current solutions are at processing full colour work.

In reference to the data presented in figure 7.4. regarding system expectation it is clear that no respondent is of the opinion that their system is a major or total failure. This is significant as it is the first indication that emerging colour systems have the capacity to satisfy users basic expectations at least. User expectation itself encompasses what any user offering colour film output facilities would expect from their own system, (i.e. delivering film output that adhered to recognised quality and production standards).

The division between user opinions regarding system expectations was again influenced by the proportion of work allocated by users to four colour processing. For example, users processing less than 50% full colour work constituted 76% of those who specified that their system ***adequately satisfied their basic expectations***. By contrast, users processing over 50% colour work accounted for 89% of those who specified that their system either ***fully met their expectations*** or ***was beyond their expectations***. Given the price/performance ratio of prepress equipment, users with a low allocation of colour work ,applying less expensive devices, were more inclined to assign rankings that reflect their systems capacity. The situation is somewhat reversed for users with a high allocation of colour work as evidenced by their favourable rankings.

The performance of users system in relation to the features listed in figure 7.4. can be ascertained by analyzing the distribution of rankings for each feature. The ranking system itself allowed users the choice of six rankings, with each rank denoting a different level of performance, as shown below:-

- Ranking of 1 = Totally Unacceptable Performance.
- Ranking of 2 = Less Than Acceptable Performance.
- Ranking of 3 = Acceptable Performance.
- Ranking of 4 = Good Performance.
- Ranking of 5 = Very Good Performance.
- Ranking of 6 = Exceptional Performance.

The features listed warrant user evaluation as they have proved problematic for PostScript based solutions in recent years.

The first feature is primarily concerned with the issue of consistent halftone production. Assessing whether current output devices are able to produce uniform pixels is vital as unwanted pixel growth, due to over exposure, can have radical effects. Given the tiny dimensions of halftone dots, normally inconsequential size variations in imagesetter pixels becomes extremely significant when creating halftones for colour images or tints. It is the amount of error in pixel size that determines the amount of error in halftone dot size. The problem is that pixels enlarge outwards, usually as a broad fringe around the edge of the pixel. However, user opinions indicate that there are no major difficulties regarding the issue of dot production given that 91% of users assigned rankings of 5 and 6 to the performance of their system.

In relation to the feature regarding rosette patterns and moiré free separations, user experience suggests that many of the screening problems associated with PostScript have, to a large extent, been resolved. Indeed, 80% of users assigned rankings of 5 and 6 to the performance of their system at delivering moiré free separations. It is interesting to note that the remaining 20% of users who assigned lower rankings were all processing less than 25% full colour work. Therefore, given such users low allocation of colour work, their low rankings are a reflection of their low level equipment. As for system performance concerning the production of rosette patterns 74% of users gave rankings of 5 and 6. As discussed earlier supercell screening involves modification of the frequency and angle elements of each screen. This may explain some of the inconsistencies users experienced in rosette production as evidenced by the number of users assigning rankings of 5 and 6, which was slightly lower than the respective figure concerning the elimination of moiré.

Having determined the overall effectiveness of new screening techniques the *one to one* interviews were an ideal opportunity in which to asses the latest screening technology i.e. FM screening. Of the eight users interviewed four had FM screening resident on their imagesetter, suggesting that the technology itself is being widely implemented by users. However, user experience has shown that demand for FM generated film is very low because customers are suspicious of its ability. One user commented "stochastic screening is resident on our machine but I think that people are very frightened about making plates from stochastic films". Another user echoed the point of low demand, commenting that "we've never thought of installing stochastic because there hasn't been any demand for it". On the rare occasions when customers did request FM output user opinion concerning its performance was divided. One user who had recently installed a *Linotype-Hell Herkules* imagesetter running *Diamond Screening* commented "I'm very pleased with *Diamond Screening* it allows me to deliver near photo quality to my customers who are very pleased with the results. Also I can process colour seps faster than *HQS* by running at a lower res". In reference to further questioning about potential difficulties in platemaking the same user responded "I've had no complaints in that department, and I think that's because we only use the *2000* film, and we calibrate our *Herkules* twice a day. Also we run test wedges on the film we send out, measure them with the densitometer to make sure the film conforms to an acceptable standard". The potential of FM screening to reduce production times via lower resolutions whilst maintaining quality was recognised by another user who said " we like it because you can run the thing at a much lower resolution, and run the text on a fifth black plate using a higher resolution, but you can run your photographs really low and you get excellent results". However, other users expressed reservations about the effectiveness of FM screening techniques. One user had ceased to offer FM screening as an option to potential customers, stating that "we don't sell it anymore because it doesn't work very well". In relation to type one user specified "we don't use stochastic on jobs with a lot of type because we tend to get a bitmap effect on the type".

Probably one of the key advantages to processing film separations using PostScript based applications is that they have the potential to deliver films that are automatically trapped, planned, and imposed. Thus eliminating the need for manual planning which significantly reduces reprographic costs, making colour more widely available. Therefore, by examining user opinion the research assessed whether emerging systems are able to deliver films that are perfectly trapped and imposed.

In relation to trapping, user opinion is encouraging given that 77% of users assigned rankings of 5 and 6 to the performance of their system. The respective figure for imposition was 68%. Again the proportion of work that users dedicated to full colour work influenced the rankings they assigned. Of the 23% of users who gave rankings of 3 and 4 to trapping performance, 75% were from users processing less than 50% colour work. Again, such users accounted for 75% of those who gave a ranking of 4 to imposition performance. The opinions of those users who were interviewed appears divided upon trapping and imposition performance. As indicated earlier one user maintained that many of their problems had arisen from customer naiveté of trapping. "Our main problem is that our customers don't understand trapping, and when trapping errors occur they assume our registration is out, when in fact it is correct, it is their files that are at fault. However, on the issue of registration the same user is surprisingly critical about the performance of the *Linotype-Hell Herkules* imagesetter. Suggesting that "it's the best guaranteed fit around, but the fit on our new *Herkules* can be a bit dubious, and it can sometimes be out by a quarter of a tick, and we'd have expected better than that". On the issue of imposition one user who had recently installed *a Scitex Dolev A2* commented that "if you have an image running over two pages it tends to give them real problems". However, the same user advocated that such problems were the fault of imposition software as opposed to hardware inadequacies.

Therefore, it is clear that successful trapping and software are reliant upon effective software driving hardware devices that guarantee consistent registration. In respect to consistent registration the favourable rankings assigned by users suggest that the latest generation of rotary drum imagesetters provide much of the precision and repeatability colour publishing requires. However, user experience demonstrates that many of the difficulties encountered may be attributable to minor software inadequacies that are exacerbated by customer naiveté.

Experience has shown that PostScript does not have an adequate description mechanism for vignettes. As a result PostScript based applications tended to break up vignettes in a large number of graduated bands. User opinion regarding the delivery of vignettes however, is surprisingly encouraging given that 85% of users assigned rankings of 4,5, and 6 to the performance of their system. There are a number of factors that may explain these unexpected results. For example, a wide implementation of *PixelBurst* chips amongst users would enable them to employ its *error diffusion algorithm* which reduces the banding that often appears in vignettes. Another possibility is that many users could be utilising a *mechanical vignette* feature that is resident on a select number of devices (e.g. Scitex Dolev) that ensures the production of smooth vignettes. Users that offer FM screening avoid the problems associated with vignette production because of its random distribution mechanism. However, it is important to realise that the factors proposed are only of a speculative nature, with the latter being the most unlikely considering the low demand associated with FM screening. The 12% of users that gave rankings of 1 and 2 were unsurprisingly from users processing less than 25% full colour work.

Throughout this investigation there has been significant emphasis on the subject of colour fidelity. Therefore, particular attention was given to the responses of users involved in the survey. From the 94% of users who allocated rankings of 4,5, and 6 it is clear that most users are content with the colour fidelity performance of emerging colour systems. Again the amount of colour work undertaken by users proved to be determining factor in the rankings they assigned, given that 73% of the 4 rankings were from users processing less than 25% full colour. The questionnaire also required users to specify whether or not they used colour matching/management software. The purpose being to establish the extent of implementation by users as well as assessing the effectiveness of such software. On the issue of implementation it emerged that only

40% of users were employing colour matching/management software in their production process. Unexpectedly the amount of colour work undertaken by users **did not** have any real effect on implementation. Of those users whose full colour work accounted for over 50% of their business the number that **did** and **did not** posses colour matching software was 45% and 55% respectively. As regards the effectiveness of such software it was found that those using it benefited from its implementation as evidenced by the following data. 71% of colour matching software users assigned rankings of 5 and 6, whereas the respective figure for those not using such software was 57%.

The majority of those interviewed did not use any form of colour management software, preferring instead to rely upon a skilled scanner operator to ensure colour fidelity. The primary function of those interviewed was to process film from discs supplied to them. Therefore users argued that maintaining colour fidelity was the responsibility of the agency/customer. All the user can really do in order to ensure accurate colour reproduction is to calibrate and maintain their output devices on a regular basis. With regard to customer responsibilities on colour fidelity one user commented "many of the customers sending us files aren't concerned about standard viewing conditions, screen calibration etc when they are working on a colour job". Indeed if one considers that many users hold customers responsible for colour quality deteriorating it seems unlikely that customers are going to be concerned with applying techniques that ensure colour matching. On the question of ensuring colour fidelity many users felt that using an experienced scanner operator to be a far more preferable option than using comparable software applications. One user commented that "with unskilled personnel using scanners 90% of the jobs can be handled by automated software. However, occasionally you're going to want to dig into the colours. Users will argue that they can achieve this by changing the colour curves in *PhotoShop*. However, such changes are performed on displays which do not provide the required accuracy". Another user commenting on this issue said "in respect to scanning images correctly that's were DTP still falls down on quality, you do need a bit of depth in the printing trade in order to scan properly". One user who described himself as "a strong advocate of DTP" expressed reservations about his own scanning ability saying "often when I scan in an image I am unable to edit the colours effectively, whereas a skilled repro operator would realise that say the yellow needs to come down 10% to print accurately". Although the above comments are of an anecdotal nature they nevertheless suggest that colour matching is not a major concern amongst customers. They also indicate that customers and users alike are far more inclined to rely upon an experienced scanner operator to ensure colour fidelity as opposed to colour management software.

Opinion appears sharply divided upon matters concerning file compression. In respect to the quantitative data the issue of file compression yielded the largest number of respondents that failed to assign any ranking (20%). Further analysis of these users system configurations revealed that all concerned did not posses file compression facilities. As for those applying file compression techniques it is clear that 71% of users enjoy very good (5) to exceptional (6) performance. These results were consistent with the qualitative data relating to compression. One user that refused to incorporate compression within their system commented "compression is not used as every other bit is taken out and therefore you're bound to get a loss in image quality. The use of compression is dependent on what you're trying to achieve and willing to accept in terms of quality". However, the experience of using compression suggest that the above opinion is ill founded. One user expressed that there were "no problems at all, our RIP will accept JPEG files as they are and decompress them and so obviously we're sending down smaller files". A user employing the *PKZip* compression tool commented "the *PKZip* can compress upto about a ratio of 8 : 1 without any loss of quality.

Therefore, it is clear that there is a wide chasm between those who refuse to implement compression, associating it with unacceptable degradation in image quality, and those who use it and endorse its performance.

Experience has shown that PostScript based screening solutions have been inadequate at reproducing metallics, fabrics, and fleshtones accurately because of the intricate detail and smooth tonal transitions associated with such features. Unacceptable moiré patterns often occur when reproducing fabrics that contain intricate and regular patterns. Also unwanted banding may appear when attempting to reproduce an image containing smooth tonal transitions. User opinions regarding the capacity of systems to accurately render such features is mixed and based upon the amount of colour work undertaken by them. Of the 60% of users assigning rankings of 5 and 6 to system performance, 81% were from those processing more than 50% full colour work. Those users processing less than 50% full colour work accounted for 79% of the 3 and 4 rankings cast.

A users allocation of colour work is of particular importance here as those processing large volumes of colour work are more inclined to posses high resolution output devices. Such devices ensure that fine detail is retained through the use of particularly fine resolutions. Finest resolution means minimum pixel size and thus a fuller range of detail. However, the problem remains; the finer the resolution, the longer the output time involved.

The response of users concerning network/server performance demonstrated that it is the most problematic issue in colour publishing, in the context of users experiences. In reference to the quantitative data only 34% of respondents allocated rankings of 5 and 6 to network/server performance, thus, making it the feature with the lowest allocation of 5 and 6 rankings. In addition, network/server performance received the largest number of less favourable 3 and 4 rankings (20% and 37% respectively). The qualitative data is consistent with the above results. On the question of colour work several users highlighted problems associated with network/server performance. One user commented "we get difficulties all the time with system crashes, especially taking a high res. scan from the *Sun Sparc* to the *SyQuest*, it seems to suffer from memory loss and first scans appear to get lost". The same user expressed reservations about the reliability of the *ISDN* system maintaining that "we never send high res. scans down the *ISDN* line". Another user who had recently experienced a substantial increase in colour work commented "we do some files of 120Mb, and calling it across the system that's when you can get problems with the system. All in all we find the system very good, but it's not as fast as we would like it to be and this is why we have to invest in a new server". As indicated above it is servers that are the major cause of the problems described. Indeed the point regarding server inadequacy has been raised previously within the investigation whereby Pfeiffer argues that *PostScript colour systems need to be configured with print servers that provide high data security* (see 4.4 *Productivity*). The notion of network/server inadequacy amongst users is not universal though as evidenced by the following extract "we've got a PS/2 RIP configured as a server and it's a magnificent piece of software. However, the majority of those interviewed expressed reservations about the performance of their network/server configuration in processing demanding colour work.

The issue of processing speed is intrinsically linked with network/server performance. Therefore it seems logical that processing speed would be adversely affected by network/server inadequacy. However, on the question of speed 62% of users assigned rankings of 5 and 6 to the performance of their system. A possible explanation for this discrepancy is that users could have been referring to the speed/performance of their RIP as opposed to the speed of their entire system. For those users who assigned low rankings to the issue of speed it is important to consider that only a small proportion of their work involved full colour work. Therefore, it is likely that such organisations would not have the required equipment to accommodate demanding and frequent colour work.

7.7 Questionnaire Conclusions

In considering the results and analysis of the questionnaire survey a number of conclusions can be drawn. The conclusions that are to be presented will not be used to validate current debate findings at this stage. Such an exercise will be the focus of chapter eight.

Probably the most important conclusions to be drawn from the questionnaire survey concern the emergence of the bureau and the deterioration in prepress quality overall, both of which have been stimulated by the ever-increasing involvement of customers in the production process itself. Therefore, the emphasis has shifted irreversibly towards PostScript applications as the means of prepress production. Many users do not hold the applications themselves responsible for the decline in quality, rather it is customer naiveté coupled with their desire to reduce costs that have caused the decline. It is clear, however, that the effectiveness of applications is based on a price/ performance ratio. The higher rankings given by users processing large volumes of colour work are consistent with this. This assumes that the amount of colour work undertaken by users determines the level of financial investment made by them.

Many of the difficulties in applying PostScript to the colour reproduction process have been resolved. In respect to PostScript screening users now enjoy consistent results, especially in terms of moiré free separations. The effectiveness of trapping and imposition applications are compounded by minor software inadequacies that are exacerbated by the inability of customers. Maintaining colour fidelity still remains the preserve of experienced scanner personnel. Users general reluctance to entrust colour management software with this task proved ill founded. File compression was an area in which user opinion was deeply divided between those who refused to use it, associating it with unacceptable image degradation, and those who implemented it and readily endorsed its performance. Therefore, there are similarities between the issues of colour fidelity and compression in that users suspicions regarding their performance are unwarranted.

The experience of users demonstrated that network/server performance is now their major concern. The inability of servers to perform effectively manifested itself as "system crashes" and "lapses in data security". Even network solutions based on the *SunSparc / UNIX* standards proved to be unreliable.

8.0 Conclusions

In considering all of the preceding information a number of conclusions can be drawn. As indicated in the introductory stages of the research a successful appraisal of emerging colour prepress developments was dependent upon satisfying a number of key objectives.

The first objective of the research sought to establish the principles and techniques involved in the reproduction of colour in a printed media. In the discussion relating to the fundamentals of colour reproduction it emerged that the principles and techniques associated with the reproduction of colour (e.g. halftoning and colour separation) are complex in terms of their operation and application. It became clear that the application of the desktop type computers to perform many of the functions associated with the reproduction of colour in any printed media has experienced significant problems in recent years. The more prominent difficulties encountered in applying the desktop to the colour reproduction process included: the moiré phenomenon in colour separation, obtaining colour fidelity between the original and the reproduction, and problems related to PostScript quality. The research then proceeded to demonstrate that a number of potential solutions (e.g. Device Independent Colour, Supercell/FM Screening Technologies, and PostScript level 2) had been developed to resolve the problems outlined earlier.

In determining that the application of the desktop had experienced a number of significant problems, it became imperative to assess whether the *solutions* to these problems were truly effective by examining current debates that challenged their viability. This in itself satisfied another key objective of the research that sought to assess whether desktop systems are able to facilitate the successful reproduction of professional colour.

The examination of current debates considered relevant to the research revealed some interesting findings which contributed to the formulation of the following conclusions.

As regards colour matching schemes it is apparent that system designers and prepress journalists are confident that systems based on device independent colour are capable of providing colour fidelity between the original and the reproduction. However, current applications based on the three stage transform should be extended to include the colour appearance model devised by Dr. R Hunt, the purpose being that its inclusion eliminates the inconsistencies that arise in the three stage transform regarding changing viewing conditions. In relation to screening mechanisms there appears to be a general consensus that existing Rational Supercell are more than acceptable for low and medium quality work. There are, however, reservations about the application of RST mechanics in high end colour work. On the issue of FM screening it is clear that advances in film technology and platemaking have addressed the major concerns amongst printers regarding the ability of FM generated films to transfer to plate consistently. However, these advances are compounded by the tendency of FM applications to produce type that suffers from jagged edges. Therefore a user's decision to implement FM screening will become increasingly dependent on the nature of type contained within a given job.

The final objective of the research involved determining the validity of current debate findings by comparing them with statistics derived from the research survey that sought the opinions of system users.

In respect to maintaining colour fidelity during the production process user opinion ,on initial inspection, reflects the arguments of Johnson and MacDonald. The majority of users abstained from using colour management applications based on the CIE standard, preferring instead to rely upon experienced scanner personnel. Users general mistrust of applications that implement the three stage transform highlights the weakness of the CIE approach. The constraints that need to be adhered to in order to be effective (see 6.1.2) are not practical given the diverse nature of prepress production. However, in contrast to this, users that implemented CIE applications enjoyed a higher degree of colour fidelity overall. Given the favourable experience of CIE users, those engaged in prepress production often do not require the degree of colour reproduction accuracy pursued by critics of CIE. Therefore, in this context, users with misgivings regarding the inability of CIE are unwarranted. Although many users still rely upon skilled scanner personnel to ensure colour fidelity it is inevitable that their role will diminish in future years. Consequently for colour critical work only there will be a requirement to develop colour matching applications that extend the accuracy of existing CIE solutions. In the wider context it is apparent from user experience that quality has deteriorated overall, thus suggesting that CIE applications perform effectively only at a lower level. However vendors need to recognise these trends and develop their products accordingly.

PostScript screening applications have experienced a number of problems over recent years. The introduction of supercell screening technology is considered by many as a major advance in the elimination of moiré. Seybold in its attempt to assess the effectiveness of supercell technology concluded that it was *acceptable for many kinds of work, but not ready for consistent high quality demands* [SEY92b]. The assessment itself was derived from an exposition in which vendors were allowed to operate and "tweak" their applications in unrealistic conditions. Indeed this point was highlighted by one of the judges appointed by Seybold who commented "in most real world situations, you don't have from 9 a.m. until 11 p.m to get the job out, with multiple tries to get it right". However, the opinions of users operating applications in the environment for which they were designed revealed that PostScript screening no longer presents a major challenge. In essence screening has become a non-issue amongst users even at high frequencies of 175 lpi and over. This conflicts with the findings of the Seybold assessment which suggested that supercell applications suffer at higher frequencies.

User opinion regarding the effectiveness of FM screening applications was consistent with current debate findings. Like Friemel, many users focused upon the suspicion that exists amongst customers regarding the ability of FM applications. Such suspicion manifested as low demand for FM generated film, which in turn persuaded some users to abstain from investing in FM applications altogether. However, the favourable experience of one user who incorporated many of Friemel's recommendations suggest that customer suspicion is unwarranted provided caution is exercised during production. One user expressed reservations concerning the ability of FM applications to render type effectively, again this is consistent with current debate findings.

The ability of emerging systems to effectively deliver films that are trapped and imposed is reliant upon operator competence. The current debate findings demonstrated that an experienced planner is able to exploit the full potential of a trapping application. However, the experience of users suggested that the situation within the graphic arts industry is radically different from the above. Many customers operating such applications are naive of the principles associated with trapping and imposition. As a consequence of this errors often occur in customer files, thereby compounding the effectiveness of such applications.

The contention that exists amongst users regarding the effectiveness of compression applications was evident in both the current debate finding and the questionnaire results. However, the assumption of the current debate findings that compression should only be used for low to medium work was not consistent with the responses of those using compression techniques in the questionnaire survey. 71% of those applying compression techniques enjoyed very good to exceptional performance, suggesting it is appropriate for high quality work as well.

The major issues of colour fidelity and screening consistency discussed in the current debate findings were not major concerns amongst prepress users. The favourable rankings assigned by them regarding the performance of solutions related to these issues suggest they have become less significant. The aspect of system performance that causes the greatest concern amongst users is network/server efficiency. This has been brought about by customers increased involvement in the production process which has had two major effects. Many of the quality aspects that were previously controlled by reprographic studios and typesetters are now the responsibility of the customer. Therefore, those offering film output services are only required to produce a level of quality that reflects customer expectations. Consequently quality no longer remains the only determining factor upon which customers decide which film output vendor is appropriate. It is the *turnaround* time that a film output vendor can deliver is of greatest interest to customers. Therefore, in order to compete, users concerns over aspects of quality have been superseded by concerns relating to the productivity and consistency of systems. This has placed significant emphasis on the performance of network/server configurations. The diverse nature of applications based on the PostScript language coupled with the large file sizes of colour work have created many networking difficulties.

The majority of current prepress networking solutions are based upon the *OPI* principle, and often incorporate the *SunSparc / Unix* standards. The general approach of such systems is to make all data simultaneously available to all workstations, via centralized storage on the file server. Use of bandwidth is often optimised by using low resolution versions of scanned images for page layout purposes, and imagesetter/high-end rotary drum recorder can be fully exploited with powerful spooling software. However, the performance of networking solutions has been shown to be lacking, characterised by "system crashes" and "lapses in data security". Data management and its ability to make prepress production more efficient is an area in which application vendors and users alike should now be focusing attention upon in order to satisfy changing needs.

Overall the investigation has satisfied its three major objectives and arrived at the conclusion that colour applications based on the PostScript language can facilitate successful prepress production. However, standards relating to quality have deteriorated significantly. This is not a consequence of PostScript application inadequacy, rather it is customer expectation coupled with their inability to manage PostScript applications effectively that have stimulated the trend of deterioration. Therefore, the emphasis has shifted away from quality related issues and more towards data management issues as application vendors and users recognise that they need to satisfy changing customer demands, namely rapid *turnaround* times.

8.1. Further Work

This investigation has ascertained the major difficulties that remain unresolved in respect to PostScript production. Many of the earlier failings of PostScript applications in relation to quality have been addressed. However smooth and efficient production is often compounded by customer naiveté and networking inadequacies. In relation to networking inadequacies further work could be orientated towards evaluating the performance of prepress data management applications. The investigation itself could establish:-

- standards upon which prepress networking solutions are based;
- problems that are encountered in prepress networking;
- current debates within the prepress community;
- user experience of networking solutions via a questionnaire survey.

BIBLIOGRAPHY

ADO91

Adobe Systems Incorporated; PostScript Language Reference Manual (Second Edition), Addison-Wesley Publishing Company,1991,pp 315-316.

AGF92

Agfa-Gaevert Ltd., An Intrduction to Digital Color Prepress (Company Brochure), 1992, pp9-13.

AGF94

Agfa-Gaevert Ltd., No Screens (Company Brochure), 1994, pp25-26.

ALD93

Aldus Corporation; Aldus Prepress Report, April 1993, page 7.

AMI91

Amidror, Isaac; The moiré phenomenon in colour separation, *Proc of Raster Imaging and Digital Typography Conf,* Cambridge University Press, 1991, pp 98-120.

ANS93

Anson, L; Fractal Image Processing, *Byte*, October 1993, pp195 - 196.

BAR93

Barnsley, M., Fractal Image Compression, AK Peters Ltd., 1993, pp 219-227.

CRO94

Crosfield Electronics Ltd., Lazl Screening Technical Information Manual, 1994.

EFI93

Electronics For Imaging Inc., Cachet Color Editor (Product Brochure), 1993, pp 2-3.

FIE90

Field, G., Color Scanning and Imaging Systems, GATF, 1990.

FIE92

Field, G., Color and its Reproduction (Revised Edition), GATF, 1992.

FOL90

Foley, James, van Dam, Andres; Computer Graphics (principles and practices) 2nd Edition, Addison-Wesley Publishing Company, 1990.

FRI94

Friemel, E., FM Screening: When Reliability in Production Takes First Priority, Deutscher Drucke, Issue 46, Dec.'94.

HAH92

Hahn, Dan; Beyond Screening:Other PostScript Quality Issues, *The Seybold Report on Desktop Publishing*, Vol.7 No.3, November 1992, pp26-29.

HIG93

HighWater Designs Ltd., CH-JPEG (Product Information), 1993.

HIL93

Hilton, D., Making the Most of JPEG Compression, HighWater Designs Product Information, 1993.

HUN87

Hunt, R.W.G; The Reproduction of Colour in Photography, Printing, and Television, 4th Edition, Fountain Press, 1987.

JEN91

Jennings, P; Goodbye Moiré, *Graphic Repro*, September 1991, pp 30-32.

JOH91

Johnson, A; Problems of Professional Image Processing with Desktop Systems, *Proc Of FOGRA Conf 1991*, April 1991, pp 1-7.

JOH92

Johnson, A.J; Device Independent Colour...Is It Real?, *Proc of TAGA Conf,* TAGA Press (Rochester N.Y), April 1992, pp81-113.

KAS92

Kasson, J, Plouffe.W; An Analysis of Selected Computer Interchange Colour Spaces, *ACM Transactions on Graphics*, Vol. 11, No. 4, October 1992, pp 373-405.

KIE91

Kieran, Michael; Desktop Publishing in Colour, Bantam Computer Books, 1991.

LAI87

Laihanen, P; Colour Reproduction Theory based on the Principles of Colour Science, *Proc IARIGAI Conf, Eisenstadt*, Vol 19, 1987, pp 1-36.

LUO92

Luo, R, Rhodes P. et al, Effective Colour Communication for Industry, Journal of *The Society of Dyers and Colourists*, Volume 108, pp 516 - 520, December 1992.

MAC92

MacGilton. Henry; PostScript By Example, Addison Wesley Publishing, 1992

MAC93

MacDonald, L.W; Gamut Mapping in Perceptual Colour Space, *Proc. of IS & T and SID Color Imaging Conf,* Transforms and Transportability of Color, pp193 - 196, November 1993.

MOL88

Molla, Rafiqul; Electronic Colour Separation, R & K Printing & Publishing Company, 1988.

OPP92

Oppenheim, A.N., Questionnaire Design, Interviewing and Attitude Measurement, p 109, Pinter Publishers, 1992.

PFE9

Pfeiffer, G; Beyond Screening: Other PostScript Quality Issues, *The Seybold Report on Desktop Publishing*, Vol.7 No.3, November 1992, pp26-29.

PUG75

Pugsley, P., Color Correcting Image Reproducing Methods and Apparatus, U.S. Patent 3,893,166, July 1975.

ROT88

Roth, S.F (editor); Real World PostScript, Addison-Wesley Publishing Co (USA), 1988.

SEY92a

Seybold, John; Adobe "PixelBurst" chip speeds RIPs, *The Seybold Report on Desktop Publishing*, Vol.7 No.3, October 1992, pp39-42.

SEY92b

Seybold, J; Color Screening Shootout Brings Surprises, *The Seybold Report on Publishing Systems*, Vol. 22, No.3, pp 1 - 18, October 1992.

SEY92c

Seybold, John; The Challenge of Colour Imaging, *The Seybold Report on Desktop Publishing*, Vol. 7 No.3, pp 19 - 25 November 1992.

SEY93

Seybold, John; Aldus shows TrapWise 2, *The Seybold Report on Desktop Publishing*, Vol.8 No.2, October 1993, pp26-27.

SEY94

Seybold, J; Keeping the High End, *The Seybold Report on Publishing Systems*, Vol. 23, No. 9, p17, January 1994.

SOS91

Sosiniski,B; Beyond the Desktop (Tools & Technology for Computer Publishing), Bantam Computer Books, 1991.

STO88

Stone M.C, Cowan W.B., et al; Colour Gamut Mapping and the Printing of Digital Colour Images, *ACM Transactions on Graphics*, Vol. 7, No. 4, October 1988, pp 249-292.

STO92

Stokes, M, Fairchild.M et al; Precision Requirements for Digital Colour Reproduction, *ACM Transactions on Graphics*, Vol.11, No.4, October 1992, pp 406-422

WOO93

Wood, Nicholas; Handling Incoming Artwork in Electronic Form (PostScript), Barco Graphics Division Handout, 1993.

APPENDICES

APPENDIX A

Figure A1

Matthew Osmond
8 Shaftsbury Close,
Thornhill,
Cardiff,U.K,
CF4 9EJ.

Scangraphic Visutek ltd
Caxton House
Leatherhead
Surrey
KT22 7TW.

Dear Sir/Madam- I am currently conducting research into computer publishing colour systems for a postgraduate research degree at the Cardiff Institute of Higher Education. I would be extremely grateful if you could provide me with any information/literature that is related to any of the areas outlined below:-

1. Configurable PostScript Interpreter (CPSI) level 2.
2. PostScript level 2 (particularly device independence colour (CIEXYZ CIE LAB colour space).
3. Janus OPI system.
4. ProfiSet software.
5. Irrational Screening technology.
6. Colour calibration & matching systems.
7. Solutions to problems caused by moire and trapping.
8. Software/hardware orientated towards colour prepress.
9. Adobe Pixel Burst technology.
10. Colour screening/separation techniques.
11. Software colour RIPs.

I understand that Mannesman Scangraphic were represented at the IPEX 93 convention, therefore, I would appreciate it if you could supply me with any pamphlets/leaflets that weredistributed by yourselves at the convention.

Yours Sincerely

Figure A2

Professional Colour with PostScript

Are you currently using or have you used a PostScript application/device to render high-end professional colour? If you are (or have) then I would be extremely grateful if you could relate your experiences of using PostScript colour *solutions* by mailing myself on A505.cihe.cf.ac.uk. I am particularly interested to hear from anybody who has opinions on the ability of PostScript in relation to the following issues of quality and performance.

1. Colour matching between the original and the reproduction, especially systems based on device independent colour i.e. CIE.

2. Screening Quality (in relation to moiré).

3. Production of rosettes, vignettes and halftone dots (dot edge and shape).

4. Speed in processing high end colour work.

5. Productivity (e.g. transmission of files, management of colour work and imposition of work, etc.).

APPENDIX B

FIGURE B1

Questionnaire

1.Introduction

My name is Matthew Osmond and I am currently conducting research into colour publishing systems for a postgraduate degree at Cardiff Institute of Higher Education. As part of my research I have designed and commissioned this questionnaire to be completed by organisations such as yours. The purpose of the questionnaire is to seek the opinion of system users on the effectiveness of their individual systems in processing and delivering acceptable colour. I would be extremely grateful for your cooperation in this survey. The time required to complete the questionnaire is approximately fifteen minutes.

2. Completing Your Questionnaire

In completing section 3 of the questionnaire entitled "Information Sought" the vast majority of questions require the respondent to tick an appropriate box or insert a value in the box provided. The information sought is subdivided into the following subsections:-

A. About Your Company.
B. About Your System.
C Your Opinion On Your Colour Prepress System.

Question (iv) of subsection C requests the respondent to make general comments on the effectiveness of their colour system. It is important that respondents answer this question in a clear and concise manner.

If you are unsure about answering any question(s) which you feel are not applicable to your organisations activities simply leave the question(s) and proceed to the next one.

On completing your questionnaire please return it using the envelope enclosed. I would appreciate it if you could return your questionnaire no later than 31/03/1994.

A. About Your Company

Company Name ______________________ Date ____/____/____

Contact ______________________ Tel. (   ) ______________________

Address ______________________

____

____

Post Code ________________

How many staff do you employ?

1-10	11-30	31-100	100+
☐	☐	☐	☐

What was the turnover of your business in 1994?

Less Than 250k	251k-500k	501k-750k	751k-1m	1m+
☐	☐	☐	☐	☐

What is the nature of your prepress business activity?

High Street Quickprint	Output Service Bureau	Repro House	Printer with own prepress dept.	Creative Bureaux
☐	☐	☐	☐	☐

How is work received?

ISDN	MODEM	DISC	FILM	ARTWORK
☐	☐	☐	☐	☐

Percentage of work is received as:-

ISDN	MODEM	DISC	FILM	ARTWORK
%	%	%	%	%

What percentage of your work is:-

Full Colour ______ %

Spot Colour ______ %

B/W ______ %

B. About Your System

1. Hardware

i. What type of scanner(s) do you use?

Flatbed	Slide	Rotary Drum	Multi Format Trannies	Other

ii. Number of bits of scanner(s) — bits

iii Maximum resolution of scanner(s) — dpi

iv. File formats supported

TIFF	DCS	EPS	PICT	PICT2	OTHER

v. Do you calibrate your scanner(s)?

Y	N

If yes see question vi below.

vi. Typical frequency of calibration — Every

vii. What workstations do you generally use?

MAC	PC	UNIX	SUN	OTHER

viii. What type of displays do you use?

MAC	PC	RADIUS	SUN	OTHER

ix. What is the resolution of the display(s) used? — X

x. Number of bits in display(s) — bits

xi. Do you calibrate your displays?

Y	N

If yes see question xii below

xii. Frequency of display calibration — Every

Question	Options
xiii. What is your primary storage medium?	Hard Drive ☐ Removable Hard Drive ☐ EMOD ☐ CD-ROM ☐ DAT ☐ Other ☐
xiv. What is your typical storage capacity?	Mb/Gb
xv. What is your primary form of output device?	Thermal Transfer ☐ Dye Sublimation ☐ Laser Printer ☐ Image-Setter ☐ Rotary Drum Film Recorder ☐ Other ☐
xvi Maximum resolution of output device(s)	dpi
xvii. Speed of output device.	ppm / cm^2/min
xviii Is the RIP of the output device PostScript based?	Y ☐ N ☐ If yes see question xix below
xix Is your PostScript interpreter from :	Adobe ☐ Hyphen ☐ Harlequin ☐ Diadem ☐ SunPics ☐ CAI ☐
xx What is your RIPs screening technology?	Irrational ☐ Rational Supercell ☐ Adaptive ☐
xxi What type of recorder does your output device(s) use?	Internal Drum ☐ External Drum ☐ Capstan ☐
xxii What is the primary function of your output hardcopy?	Proofs ☐ Colour Separations ☐ Other ☐ If other please specify in the space below
xxiii Do you calibrate your output device(s)?	☐ ☐ If yes see question xxiv overleaf.

xxiv Frequency of output device calibration

Every.

2.Software

i. What type of page composition software do you use?

Aldus Pagemaker	Quark Xpress	Letraset Des. Studio	Interleaf Publisher	Ventura Publisher	Other

ii What type of colour separation software do you use?

Adobe Photoshop	Aldus Preprint	Spectre Seps	Publisher Prism	Other

iii What type of draw programs do you use?

Adobe Illustrator	Aldus Freehand	Corel Draw	Canvas	Other

iv What type of colour management software do you use?

Apple Coloursync	Spectre PrintPro	EFI Colour	KodakCMS	Agfa Fotoflow	Linotype Colour

v. Do you use any of the following "specialist" packages?

Aldus Trapwise	Aldus Presswise	Tektronix TekColour	Other

If other please specify the "specialist" software you use in the space provided below.

Other software used.

vi. What type of system is your software configured to?

OPI	DCS	Other

If other please specify the software configuration in the space provided.

Other software configuration used.

C. Your Opinion On Your Colour Prepress System.

i At what level does the system meet your expectations?

Beyond your expectations	Fully Meets your expectations	Adequately satisfies your basic expectations	Fails to meet the majority of your expectations	Totally fails your expectations

ii Concerning your colour publishing system please rank the performance of your system (using the scale provided) on the features outlined below at the screen frequencies indicated. Alternatively you can insert an overall ranking instead.

Totally Unacceptable					Exceptional
1	2	3	4	5	6

Screen Frequency	100 lpi	133 lpi	150 lpi	175 lpi	Overall
Producing Consistent Halftone Dot Shape					
Delivering Consistent Halftone Dot Edges					
Rendering Area/Colour Smoothness					
Producing Consistent Rosette Patterns					
Delivering Moire Free Colour Separations					
Ensuring Accurate Trapping					
Delivering/Handling Vignettes					
Colour Matching Capability					
Unsharp Masking Adaptability					
Under Colour Removal Capability					

Screen Frequency	100 lpi	133 lpi	150 lpi	175 lpi	Overall
File Compression/Decompression performance					
Colour conversion between varying devices (e.g scanner,printer)					
Reproducing metallics, fleshtones and fabrics					

iii Now rank the performance of your system (using the scale provided) on specific issues related to prepress colour quality listed below:

Totally Unacceptable					Exceptional
1	2	3	4	5	6

Speed in processing colour images/colour separated halftones	
Reliability in producing colour images	
Ease of use	
System/Device(s) range of features	
Workflow through the system	
Screening quality	
System/Devices fully meet their product specifacations	

iv If you have any additional comments you wish to make regarding the effectiveness of your colour publishing system please include these in the space provided.

Figure B2

A. About Your Company

Company Name ____________________ Date ___/___/___

Contact ____________________ Tel. (   ) ____________________

Address ____________________

____

____

Post Code ______________

How many staff do you employ?

1-10	11-30	31-100	100+
☐	☐	☐	☐

What was the turnover of your business in 1994?

Less Than 250k	251k-500k	501k-750k	751k-1m	1m+
☐	☐	☐	☐	☐

What is the nature of your prepress business activity?

High Street Quickprint	Output Service Bureau	Repro House	Printer with own prepress dept.	Creative Bureaux
☐	☐	☐	☐	☐

How is work received?

ISDN	MODEM	DISC	FILM	ARTWORK
☐	☐	☐	☐	☐

Percentage of work is received as:-

ISDN	MODEM	DISC	FILM	ARTWORK
%	%	%	%	%

What percentage of your work is:-

Full Colour ______ %

Spot Colour ______ %

B/W ______ %

B. About Your System

1.Hardware

Input Specifacations

What type of scanner(s) do you use?

Number of bits of scanner(s) BITS

Maximum resolution of scanner DPI

File formats supported

TIFF	DCS	EPS	PICT	PICT2	OTHER

Workstation/Display Specifacations

What workstations do you generally use?

RAM	Hard Disc Mb
Processor	Clockspeed

What type of displays do you use?

Resolution x	Number of Bits
	Size

Output Specifacations

What is your primary form of output device(s)?

Resolution dpi	Output Speed ppm/cm^2 per min

Is the RIP PostScript based? Y N

Who is your PostScript interpreter from?

What is your RIPs screening technology?

Irrational	Rational Supercell	Stochastic	Adaptive

What type of recorder does your ouput device (s) use?

Internal Drum	External Drum	Capstan

What is the primary function of your output hardcopy?

Colour Film Separations		Percentage of total output	%
Proofs		Percentage of total output	%
Paper Output		Percentage of total output	%
Other		Percentage of total output	%

2. Software

What type of page composition software do you use?

What type of colour separation software do you use?

What type of draw programs do you use?

What type of colour management software do you use?

Other Software used (e.g. JPEG, Trapwise, PressWise etc)

What type of system is your software configured to?

OPI	DCS	Other
	√	

Briefly describe your network/server configuration

C. Your Opinion on Colour Prepress

i. What criteria do you set yourself in relation to the quality of the colour you produce?

ii. What do you see as the main problems (if any) that remain unresolved in applying DTP to process professional colour?

iv. Have you experienced any significant changes in the type of colour work now being processed by you in relation to that undertaken in recent years?

v. What have been the main factors in stimulating the changes you describe?

vi. What do you believe have been the major changes in the colour prepress market over recent years?

vii. What future developments do you envisage regarding the colour prepress market?

viii. To what extent are you concerned about maintaining colour fidelity between the original and the final output?

Deeply Concerned	Concerned	Not Very Concerned	Not at all Concerned	Concern varies according to customer expectations
☐	☐	☐	☐	☐

If you indicated that maintaining colour fidelity was important to you please answer questions ix - x.

ix. What methods do you employ in order to ensure colour fidelity between the original and the reproduction?

Calibration of Device(s)	Colour Management Software	Pantone Type Reference	Combination of Methods Outlined	Other
☐	☐	☐	☐	☐

If other please specify

x. Maintaining Colour Fidelity

(Complete only those question(s) that are appropriate to the methods used by you).

A. Calibration

Input

Device	Method of Calibration	Frequency of Calibration
Device	Method of Calibration	Frequency of Calibration
Device	Method of Calibration	Frequency of Calibration

Display

Device	Method of Calibration	Frequency of Calibration
Device	Method of Calibration	Frequency of Calibration
Device	Method of Calibration	Frequency of Calibration

Output

Device	Method of Calibration	Frequency of Calibration
Device	Method of Calibration	Frequency of Calibration
Device	Method of Calibration	Frequency of Calibration

B. Colour Management Application (CMA) Software

What features of your CMA application do you primarily use to maintain colour fidelity?

How effective do you believe your CMA to be in maintaining colour fidelity?

C. Please specify any other methods used in maintaining colour fidelity (e.g. Pantone reference type system, use of densitometers etc..).

Method(s)

Effectiveness of method(s) specified

xi. Colour Screening Quality

Could you please rate the performance of your current screening mechanism on the following issues of quality using the ranking scale provided.

Totally Unacceptable					Exceptional
1	2	3	4	5	6

Producing Consistent Halftone Dot Shape ☐

Delivering Consistent Halftone Dot Edges ☐

Producing Consistent Rosette Patterns ☐

Delivering Moire Free Separartions ☐

Is the quality of your screening mechanism affected by variations in frequencies?

Y ☐ N ☐

(if Y, to what extent do variances in frequencies affect quality)

Significantly Affects Quality ☐ Marginal Affect On Quality ☐ Negligible Affect On Quality ☐

xii Compression Issues

What are the major benefits in using compression techniques in processing colour work?

What are your typical compression ratios for colour work? :

What would be your maximum compression ratio for colour work? :

Do you use selective compression techcniques (JPEG++etc)? Y N

What difficulties(if any) have you encountered in using compression techniques for processing colour work?

xiii. Network/Server Considerations

What difficulties (if any) have been encountered as a consequnce of network/server inadequacy?

xiv. User Familiarity

How many applications are you currently using that are in some way involved in processing and manipulating colour work?

Colour Applications

How would you asses your competence in using them?

Fully Competent in all Colour Apps.	Fully Competent in the Marity of Colour Apps.	Fully Competent in 1-3 Colour Apps.	General Competence in all Colour Apps.

By what method(s) did you aquire the skills necessary to operate them effectively?

College Based Training	Training at Workplace	Training Given by Supplier of Application	Via manuals & tips/tricks type books	Other

(If other please specify)

Through which medium did you obtain your current applications?

Direct From Manufacturer	Retail Outlk	Sales Representatives	Other

(If other please specify)

What post sales support (if any) is provided by vendors of applications and devices?

To what level has the training you have received on colour applications allowed you to exploit their potential?

Fully exploit all applications	Fully exploit the majority of colour apps.	Fully exploit 1-2 colour applications	Do not exploit any of the colour apps. to their full Potential	Only fully exploit those features of a colour app. that are appropriate to your work
☐	☐	☐	☐	☐

xv. General Colour Issues

Please rank the performance of your system (using the scale provided) on specific issues related to prepress colour quality listed below:

1	2	3	4	5	6

Speed in processing colour work/colour separated haltone film.	☐
Performance of your network/servers in processing large colour files	☐
Ensuring accurate trapping.	☐
Ensuring Accurate Imposition of Pages	☐
Maintaining Colour Fidelity between the original and the reproduction.	☐
File compression/decompression in relation to its effect on image quality.	☐
Delivering/handling vignettes	☐
Reproduction of metallics, fleshtones, fabrics.	☐

If you have any additional comments to make regarding the effectivenessof your colour publishing system pleaseinclude them in the space provided.

APPENDIX C

LIST OF ACRONYMS

AAS	Adobe Accurate Screens.
ABS	Agfa Balanced Screens.
ASIC	Application Specific Integrated Circuit.
CIE	Commission de I' Eclairage.
CMYK	Cyan, Magenta, Yellow ,Black.
CRT	Cathode Ray Tube.
CTU	Colour Transform Unit.
DCT	Discrete Cosine Transform.
DMA	Direct Memory Access.
DPI	Dots Per Inch.
DSC	Document Structuring Convention.
DTP	Desk Top Publishing.
EFI	Electronics For Imaging.
FM	Frequency Modulated.

HSL	Hue, Saturation, and Lightness.
HQS	High Quality Screening.
JPEG	Joint Photographic Experts Group.
KCMS	Kodak Colour Management System.
LCH	Lightness, Chroma, and Hue.
LPI	Lines Per Inch.
PPC	Print Process Calibration.
RGB	Red, Green, and Blue.
RIP	Raster Image Processor.
RISC	Reduced Instruction Set Computing.
WYSIWYG	What You See Is What You Get.